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AN

INTRODUCTION
TO THE
STUDY OF CHEMISTRY,

EXPLAINING ITS PRINCIPLES,
AND THEIR
APPLICATION TO ARTS, MANUFACTURES,
&c. &c. &c.

IN
A CLEAR AND FAMILIAR MANNER.
WITH AN
APPENDIX,
CONTAINING THE MODERN THEORY.

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DEDICATION.

TO

ROBERT PERCEVAL, ESQ. M.D.

PROFESSOR OF CHEMISTRY

IN THE

UNIVERSITY OF DUBLIN.

DEAR SIR,

I Beg leave to inſcribe to you this Introduction to your favourite Science, as a teſtimony of my ſincere Eſteem for your Talents and Virtues. Although in many reſpects it may fall ſhort of what I wiſh, and you deſerve, yet, in one point of view, it can with ſome confidence lay claim to your notice, as being an attempt to enlighten and improve the young and uninformed mind. This has ever been the object of your active and perſevering exertions; and has diſtinguiſhed your character, as a Profeſſor, not leſs than the clearneſs, order, and preciſion of your Inſtructions. Upon theſe topics I might expatiate with great pleaſure; but conſulting your feelings rather than my own, I ſhall be ſilent.

I AM, DEAR SIR,
WITH UNALTERABLE REGARD,
YOUR MOST FAITHFUL FRIEND,
&c. &c. &c.

RICHARD STACK.

DUBLIN,
FEBRUARY 1802.

PREFACE.

BEFORE the Reader enters upon the following Work, it ſeems proper to ſay a few words upon its nature and deſign; which will enable him to judge how far it is calculated to attain the ends propoſed—to convey uſeful information, and to facilitate the ſtudy of a beautiful and important branch of knowledge. With regard to the ſubject itſelf, little need be offered by way of recommendation. Chemiſtry is at preſent eſteemed by all men of letters to be an object of high excellence and utility. As ſuch, it has of late years been cultivated with ſo great induſtry and talents, that it claims very general attention, and merits a diſtinguiſhed place in the Syſtem of Education. Even in the light of an accompliſhment, no ſtudy has become more indiſpenſable; for none is more frequently matter of diſcourſe in polite and well educated ſocieties. But, as a valuable improvement of the mind, it ranks ſtill higher; for no ſubject gives a more extenſive and intimate acquaintance with the works of Nature.

Moſt of the books, profeſſedly written upon Chemiſtry, appear to be rather too learned, voluminous, and abſtruſe, for the common claſs of readers, and to be principally adapted to men of ſcience and reſearch. There are others, it is true, more plain and familiar, in which the ſubject is incidentally mentioned: but theſe, being intended for mere rudiments, or being deſultory treatiſes, containing various matters beſide thoſe purely chemical, cannot be expected to afford, upon this particular head, information of much extent, method, or value. To remedy theſe inconveniences, an elementary or introductory Treatiſe ſeemed wanting; which, without entering too far into the refinements of the ſcience, ſhould collect a conſiderable variety of uſeful matter, arrange this in perſpicuous order, and explain it in a clear and proper manner.

Were we to detail the whole extent of this ſcience, we ſhould have to enumerate moſt bodies upon the ſurface, and in the bowels of the earth; with many of the moſt ſtriking and important phenomena of Nature: and not only theſe, but a multitude of arts and manufactures, which owe to its diſcoveries their invention or improvement. This vaſt extent, while it adds to the importance of the ſtudy, naturally encreaſes its labour and difficulty, ſo as to render it ſcarce compatible with the attainment of other uſeful knowledge by the young ſtudent, unleſs brought within ſome reaſonable compaſs. The ſame may be ſaid of perſons of greater maturity; many of whom would certainly deſire ſome general acquaintance with the ſubject, although prevented by their duties and avocations from devoting to it a great deal of time and attention. It was with a view to accompliſh ſo deſirable an end, that the preſent Work was undertaken and conducted. Upon the different Theories, and ſubtle Diſquiſitions, to which the ſcience has given riſe, it ſpeaks little. Plain facts are its chief concern; and even of theſe, ſuch, almoſt excluſively, as have been applied to practice, and go to eſtabliſh the principles, in which all Chemiſts are agreed. From the almoſt infinite number and variety of chemical combinations, many have been retrenched, and the view confined to thoſe of moſt importance. To give an inſtance of this: The acids of different ſubſtances have, for the moſt part, a ſtrong tendency to unite with other bodies. But the ſulphuric, nitrous, and marine acids, poſſeſſing this property in an eminent degree, and having the moſt extenſive application to the ſeveral arts and uſes of life, are not only treated moſt diffuſely in themſelves, but likewiſe their combinations with metallic and other ſubſtances are diſtinctly conſidered; whereas, the other acids are more ſlightly examined, and only ſuch combinations of them noticed, as have been employed, or ſeem to conduct, to ſome valuable purpoſe.

The ſame attention to clearneſs and utility regulates every other part of the Work. Subjects of daily obſervation and experience, which have been applied to the benefit and convenience of Man, are ſelected, and treated with all poſſible plainneſs, as well in ſtating, as in accounting for the facts—a method, which, it is conceived, will be likely to introduce the ſtudent in an eaſy and agreeable manner to a more accurate ſtudy of Chemiſtry, ſhould his taſte lead him that way;

but which, at all events, will furniſh his mind with a great deal of ſolid and delightful inſtruction. Among other ſubjects, the beautiful and uſeful arts of Pottery, from the fineſt porcelain to the coarſeſt ware; the making of Soap, Glaſs, &c.; the obtaining of Salt, Saltpetre, and Gunpowder; the working of mineral Ores, and of Metals; Refining, Gilding, Enamelling, Diſtilling, Dyeing, with many more, equally inſtructive, will be found here. And when theſe practical and important matters have been clearly and ſatisfactorily explained in their principles, the ſtudent will then be better prepared to advance into the higher and more arduous walks of the ſcience, and to proceed in his courſe with leſs labour and trouble.

In ſtating the Experiments, a ſimilar rule has been obſerved. Inſtead of detailing all their particular and minute circumſtances, which would too much embarraſs the mind, and impede its progreſs toward general knowledge, at the ſame time rendering the work more complicated and tedious, the attention is directed to the main points on which the Experiment turns; and the moſt eaſy forms of expreſſion, conſiſtent with a juſt and clear explanation of its principles, are employed. This kind of preparatory knowledge will, as it were, clear the ground, and open the view; and will enable the ſtudent to examine at more leiſure and with greater attention thoſe nice and delicate points which may afterwards occur, and which cannot be perfectly underſtood perhaps, unleſs by a view of the Experiments themſelves. If any exceptions to this ſimple method ſhould be found, they are caſes more immediately concerning arts, manufactures, or ſome other practical purpoſe, and on theſe accounts they are treated more fully and explicitly.

Upon the ſame grounds alſo, the new Syſtem is annexed, by way of Appendix, inſtead of being incorporated into the Work: which method, though it may be leſs ſcientific, appears to be much better adapted to the eaſe and convenience of the ſtudent, and more agreeable to the common order of his conceptions. Beſides, it ſhould be conſidered, that this ſyſtem has adopted a number of new and difficult terms of art, which, in an early ſtage of the buſineſs, might too much diſtract the attention, or burthen the memory. Indeed one of the great obſtacles in the way of learning Chemiſtry, ariſes from its copious nomenclature: and therefore it ſeems beſt, in an elementary treatiſe, not to impoſe an additional burthen, before ſome acquaintance ſhall have been made with the ſcience. The new nomenclature, being framed upon chemical principles, muſt be difficult to perſons wholly ignorant of theſe, but will appear to all, who underſtand them, perfectly ſimple in its conſtruction, ſoon learned, and eaſily retained. Familiar objects, for this reaſon, are firſt preſented under familiar names, and afterwards thoſe which are moſt ſcientific and remote from common uſe. But the old doctrines are alſo laid down in ſuch a manner, as in ſome ſort, to prepare for the new, without as yet adopting the terms. Thus, vital air, being a conſtituent part of our atmoſphere, is in the Work treated under the general head of AIR: but, at the ſame time, the opinion of thoſe Chemiſts is there ſtated, who look upon it to be the principle of combuſtion and of acidity. Now the new doctrine calls it the acid principle, under the name of Oxygen Gas. Here then is no inconſiſtency; and certainly, whatever be the nature of the ſubſtance in queſtion, as it is allowed on all hands to be a conſtituent part of our atmoſphere, it may fairly be treated under that head. There is another circumſtance in the new ſyſtem, which further recommends the method adopted, as more ſuitable to the Work. In Mathematics, the propoſitions called Axioms and Poſtulates are admitted as ſoon as heard; and, from their ready admiſſion, we are led on to truths of a more complex nature. It is otherwiſe in the new ſyſtem of Chemiſtry, which may be almoſt ſaid to open with the deciſion of a nice and important queſtion, and to lay down as principles, what have been eſtabliſhed upon the labours of perſevering induſtry, joined to refined ſagacity. It may be ſaid, perhaps, that they are founded in experiments, which fairly prove them. But even granting this, the objects are too volatile and aerial for the graſp of the untutored mind; and we had better make known the exiſtence and obvious properties of ſuch ſubſtances, before we commit their management into ſuch unſkilful hands. However, to prevent all objection on this ſcore, the new Theory is laid down briefly in the Appendix, in ſuch a manner, that the old may eaſily be accommodated to it, as well in method as in terms; and a Table is added, giving at one view the principal combinations, with their reſpective names in each ſyſtem.

It has been a point of no ſmall difficulty, to draw the line of ſeparation between thoſe things, which were proper to be admitted, and thoſe which the nature of the Work was obliged to exclude. The man of ſcience will perhaps think too much has been pared down; while the lazy and ſuperficial reader may wiſh that more had been retrenched. To theſe objections the anſwer is obvious. It was not deſigned for either of theſe deſcriptions of perſons; but for thoſe who, being unacquainted with the ſcience, ſeek for general yet ſound inſtruction, combining theory with practice; eaſy, yet not puerile; and rational, though not refined.

Such are the nature, deſign, and general plan, of this familiar Treatiſe now offered to the Public. Should they be approved, and the execution be found ſo far to correſpond with them, as to facilitate, and thereby diffuſe more widely the ſtudy of this valuable branch of knowledge, the writer will conſider his time and pains well beſtowed. It pretends to no new diſcoveries, but only to the choice and arrangement of materials, which have been employed by approved writers. To deliver theſe with clearneſs and ſimplicity is its chief aim. With the philoſophic Chemiſt is left for the preſent the proſecution of his abſtruſe and ſublime diſcoveries; yet not without entertaining an hope, that the ſtudent, thus inſtituted, may at ſome future period emulate his ſtudies, and profit by his example.

One claſs of Students ſeem particularly called upon to give attention to this ſcience; I mean the Students of the Univerſity. Their ſituation, the habits of cloſe reaſoning ſo well taught by their academic courſe, and the opportunity of hearing Lectures, both public and private, delivered in the College; theſe, with others that may be named, are very peculiar advantages. Yet theſe advantages are loſt to many, for want of ſome general information upon the ſubject; which would naturally lead them to attend thoſe experimental courſes, that ſo fully prove, and ſo clearly illuſtrate its doctrines. Such are their particular inducements; and if example might quicken their ardour in this purſuit, there are not wanting able and learned men of our own country, who have adorned the ſubject with the moſt uſeful diſcoveries, and the moſt enlightened views.

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SECT. I.

OF

CHEMISTRY IN GENERAL,

AND

OF THE SUBSTANCES

COMMONLY CALLED

ELEMENTS.

CHAP. I.

CHEMISTRY DEFINED: ITS METHOD, AND TERMS OF ART EXPLAINED, AND THE SUBJECT DIVIDED.

CHEMISTRY is a Science, which teaches the knowledge of ſuch mutual actions of the minute parts of inanimate bodies, as produce evident changes therein. Theſe actions do not take place, unleſs when the particles of thoſe bodies are in contact, or at very ſmall diſtances from each other. They are therefore very ſlight between ſolid bodies, whoſe rigid and unyielding forms prevent the parts from coming near each other in any conſiderable number: whereas it being the property of fluids to inſinuate themſelves into the pores and interſtices of ſolid bodies, they can in ſo doing, bring about a cloſe communication between the parts of both, in a great variety of points, and in all directions. Hence it has become nearly a maxim in this ſcience, that bodies do not act chemically upon each other, except one of them at leaſt be in a fluid ſtate.

There are two methods of producing this fluid ſtate, ſo neceſſary in chemical proceſſes; by water and by fire. The parts of ſome bodies are diſſolved by water, or by ſubſtances which by means of water are in the ſame kind of fluid ſtate with it. Others are melted into a liquid ſtate, or driven off in vapour by fire; which vapour is only a fluid under another form. Operations made in the former manner, that is, by means of a ſubſtance which is commonly in a fluid ſtate, are ſaid to be made in the *humid or moiſt way:* operations made in the latter, by the application of heat, are ſaid to be made in the *dry way.*

All theſe operations are ranked under two general heads, viz. *Analyſis* and *Syntheſis.*

Analyſis, or Decompoſition, conſiſts in reſolving compounded bodies into ſuch ſimple component parts, as are heterogeneous, *i. e.* of different kinds. To illuſtrate this: If a well-known mineral ſubſtance, called Copperas-ſtone, be expoſed to a certain degree of heat, it will ſoon be reſolved into melted ſulphur and iron: and if the operation be made in a cloſe veſſel, and the heat be encreaſed, a yet more complete ſeparation will take place, the ſulphur being driven off to the top of the veſſel in the form of vapour and there collected in a ſort of powder, while the iron remains below. Whence it is manifeſt, that the chief ingredients, which compoſe that compounded ſubſtance, are ſulphur and iron.

Syntheſis, or Compoſition, conſiſts in combining ſimple heterogeneous ſubſtances, ſo as to form a compound. Thus as before: If ſulphur and iron be mixed together in a melted ſtate, they form an artificial mineral reſembling the Copperas-ſtone in its nature and properties. And hence we have an additional proof of the former concluſion, that ſulphur and iron are the chief component parts of that natural compound mineral ſubſtance. Both theſe methods are employed in chemical enquiries; and they are uſeful if not neceſſary, for the purpoſe of illuſtrating and comfirming each other; as is plain from the inſtance juſt now mentioned.

Chemical combination differs from all other ſorts of compoſition of matter; whether theſe be made with ſubſtances of the ſame kind, which form compounds called *Aggregates*; or by blending together ſubſtances of different kinds, without effecting an intimate union between their minute parts, which form what are called *Mixtures*; or by any other means whatſoever, where the component parts do not ſenſibly act upon

each

each other. In ſuch caſes the only change, that takes place, is merely in the weight and bulk of the bodies: whereas in chemical combination, the compound has for the moſt part properties entirely diſtinct from either of the component parts. Thus two certain ſubſtances, called an Acid and an Alkali, each of which burns and corrodes the fleſh of animals, being united form a compound perfectly harmleſs; and thus two fluids, each quite colourleſs, form a ſtrongly coloured compound. So that an entire change of principles here ſeems to take place, and the bodies (as Chemiſts ſay) to penetrate each others dimenſions. Chemical combination may be defined then, according to Mr. Kirwan, that power, by which the inviſible parts of different bodies intermix, and unite ſo intimately, as to be inſeparable by mere mechanical means.

The mutual actions of bodies, called by Chemiſts *Attractions*, vary greatly in different bodies: for while ſome attract each other with great rapidity and force, others do ſo but ſlightly; and others hardly ſhew the leaſt diſpoſition to unite. On theſe accounts it has been found convenient to note down ſeveral of the moſt remarkable and moſt important to be known, in tables called *Tables of Affinities* or *Elective Attractions*. The principle, upon which this is done, may be explained by an eaſy and familiar inſtance. Suppoſe common ſalt to be diſſolved in water contained in a glaſs; if ſpirits of wine be poured in the two fluids will combine,

bine, and the ſalt being diſengaged from the water will be ſeen to fall to the bottom. The water is therefore ſaid to have a ſtronger affinity or elective attraction to the ſpirit of wine, than it has to the ſalt. It may here be obſerved that this is an inſtance of Analyſis and Syntheſis in the humid way; the ſpirit of wine having reſolved the fluid into which it was poured, into its component parts ſalt and water; with the latter of which it then becomes combined, and forms a new compound. In this experiment the water is called the *Solvent* and ſometimes the *Menſtruum*: the ſpirit of wine is the *Precipitant:* the mixture of ſalt and water, as alſo the ſucceeding one of ſpirit of wine and water, are called *Solutions* of thoſe reſpective bodies in the water: and the ſalt, which fell to the bottom, is called a *Precipitate*, but may better be deſcribed by the name of *ſeparated Principle;* becauſe the diſengaged ſubſtance does not in all caſes fall to the bottom. Another point worthy of obſervation is, that the ſeparated principle is ſometimes though ſeldom pure, that is, has undergone no change, either by the action of the body with which it had been united, or by that of the body which ſeparates it: and it is ſometimes impure on either or both of theſe accounts.

The elective attractions, of which an inſtance has been already given, are called *ſimple elective Attractions*. There are others, of which examples frequently occur, called *double elective Attractions*

tractions; which will be beſt explained by another inſtance. If volatile alkali or ſpirit of hartshorn be combined with acid or oil of vitriol, and the ſolution be poured upon common ſalt, which conſiſts of the marine acid and mineral alkali, a double change will take place by elective attraction; the acid of vitriol will unite with the mineral alkali, and form a ſalt known by the name of Glauber's ſalt from its inventor, while the marine acid and volatile alkali, being ſet free, will be attracted to each other, and form a ſalt called ſal ammoniac. This kind of attraction frequently takes place between two compounded bodies, where the component parts of one in their ſeparate ſtates have no power of decompoſing the other.

From the foregoing ſtatement a general conception may be formed of the object of chemiſtry; its method of proceeding; the nature of chemical combination, and elective attraction. There are many particular means employed for carrying theſe into effect, and thereby attaining the important ends of chemical enquiries: Such of them, as will be often mentioned, are for the greater convenience here explained.

If any body be diſſolved in a fluid, the ſolution can proceed only to a certain point, when the fluid will become unable to take up more of the body: this is called *Saturation.* The point of ſaturation varies even in the ſame fluid: thus in moſt caſes it is higher in hot than in cold water, the former being able to hold in ſolution a greater quantity of the ſoluble ſubſtance than the latter.

If a fluid be expoſed to heat, natural or artificial, or to air and particularly dry winds, it will gradually be diſſipated in the form of vapour; as is manifeſt from water which has been boiling for ſome time, or lying expoſed to the ſun and air. This is called *Evaporation*: and it is always the greater in proportion as the ſurface expoſed is larger, and the weight of the air leſs.

Concentration is the ſtrengthening of a ſalt diſſolved in any watery fluid, which is done either by evaporating part of the water, or by cauſing it to freeze, and taking away the ice: for the evaporated water, and the ice, are both freſh, and conſequently the remaining fluid is more ſtrongly impregnated with ſalt, as containing the ſame quantity in a leſs meaſure.

Cryſtallization is that property of bodies, by which they are diſpoſed, when changing from the fluid to the ſolid ſtate, to take regular forms called *Cryſtals*. Thus, if common ſalt be diſſolved in water, and you evaporate the ſolution by a gentle heat, the fluid will become ſolid, and the ſalt will form itſelf into ſix-ſided cryſtals called cubes. Each ſalt has its own peculiar forms, which it invariably aſſumes.

Condenſation conſiſts in cooling bodies, ſo as to change them from a fluid to a ſolid ſtate, as water becomes ice; or from vapour to fluid, as ſteam is changed into water.

Diſtillation is the proceſs, by which the volatile parts of bodies, *i. e.* thoſe moſt eaſily driven off by heat, are raiſed in the form of vapours; which vapours are afterwards condenſed, and obtained in a liquid form. A *Still* therefore conſiſts of two parts; one, in which the evaporation is made by the application of heat; the other, in which the vapour is condenſed by cold. *Retorts* are veſſels uſed for this purpoſe: they are of a globular form; of earthen ware, metal or glaſs; with a neck bent on one ſide, which may be inſerted into the neck of another veſſel uſually of glaſs, and of a round form, which is called the *receiver*. When the ſubſtance to be diſtilled is heated in the retort, its volatile parts paſs over into the receiver, where they are condenſed: the parts which remain behind in the retort, are called the *reſidue*, and, as oppoſed to the volatile parts, are called *fixed*. Retorts are generally bedded in ſand, which is kept heated to any degree thought proper, ſhort of what is ſufficient to melt the retort. This bed of ſand is called a ſand bath: and, beſides the advantage juſt mentioned, is an excellent means of keeping the heat uniform.

In the common Still, the pot ale or whatever ſubſtance is to be diſtilled is put into the body of the ſtill; the vapour, being driven up into the head, is made to paſs thence through a long ſpiral tube called the *worm*; and being here condenſed into an ardent ſpirit, by means of a veſſel of cold water, through which the worm paſſes, it drops into another veſſel placed beyond that which contains the water.

Rectification is the diſtilling again of the former product. Thus the ſpirit which came over, and was obtained in the laſt experiment, being again diſtilled, will give a rectified ſpirit.

If the volatile parts, when collected, be dry inſtead of fluid, the proceſs of diſtilling is called *Sublimation*. It is ſo called, becauſe they are driven up by the force of fire, and are collected at the top of the veſſel at a diſtance from the reſidue. Such are the flowers of brimſtone. Theſe ſolid products are for the moſt part called *Sublimates*.

It is ſometimes convenient to expoſe mineral ſubſtances to the fire in open veſſels, or in immediate contact with it, for the purpoſe of diſſipating their moſt volatile parts: thus ſulphur, which is often found in metallic ores, is driven off by a heat, weaker than what is ſufficient to make a change in other matters of the ores. This proceſs is called *Roaſting*. The veſſels uſed by Chemiſts for this and the following proceſſes are called *Crucibles*.

Fuſion conſiſts in heating ſolid bodies either in cloſe or open veſſels, till they become fluid: As lead and other metals are made to melt.

Calcination by fire conſiſts in expoſing bodies to heat in open veſſels ſo long, that no farther change can be produced in them by fire: and the ſubſtance which remains, and is incapable of any farther change, is called a *Calx.* Thus copper, iron, and moſt metals are by a ſtrong and continued heat converted into dull and brittle ſubſtances without metallic ſplendour, and which fall into powders of different colours. The ſame effect is alſo produced in other ways as well as by fire; as by the action of acids upon other bodies. Thus iron is calcined by acid of vitriol; for if an Alkali be added to their ſolution, the iron is precipitated in the form of a dark powder like what is produced by the action of fire.

The *temperature* of any body is its *power* of exciting ſenſations of heat or cold; and the greater the ſenſation of heat, the higher is the temperature ſaid to be. Its degree is *meaſured* by the quantity of heat, which the body communicates or gives out to other bodies, as will appear more fully hereafter, when we come to treat of the thermometer.

Chemiſts have divided all natural bodies into three deſcriptions, called kingdoms; viz. the *Mineral*, the *Vegetable*, and *the Animal.*

The mineral kingdom comprehends all the unorganized ſubſtances which compoſe the maſs of our globe. Theſe, although ſubject to certain laws of motion, have in themſelves no powers of life or action.

The vegetable kingdom includes thoſe bodies, which conſiſting of organs, and veſſels fitted to ſupply juices, to receive nouriſhment, and to propagate life, have ſeveral functions depending upon their ſtructure, as growth, digeſtion, &c. &c.

The animal kingdom poſſeſſes all the properties now mentioned and over and above theſe, the properties of moving from place to place, ſenſation perhaps, and ſome others which vegetables ſeem to want.

CHAP. II.

Of the Subſtances commonly called ELEMENTS; *and firſt, of* FIRE.

IT was an opinion entertained by ſome ancient philoſophers, that Fire, Air, Water, and Earth, were the Elements or Principles of all things; whoſe combinations and modifications produced the different kinds of natural bodies. This opinion is now known to be very far from preciſe or juſt: ſome of theſe ſubſtances being diſcovered to be themſelves compounded, and capable of being reſolved into different component parts; while other ſubſtances, not ranked among them, have never yet been analyzed, and muſt therefore be conſidered as ſimple bodies. But theſe Elements, as they are called, being ſubſtances very familiar to our ſenſes, and meeting our daily obſervation, ſeem to be proper for an early examination in a work like the preſent; eſpecially as by the caution obſerved here, there is no danger that they will be looked upon as chemical principles in a ſtrict and philoſophical ſenſe. We ſhall therefore firſt examine theſe, and afterwards ſuch ſubſtances, as cannot be reduced into any of them.

Fire is ſuppoſed to be a fluid of a very ſubtil, active, and penetrating nature, whoſe parts are in continual motion. But this fluid never has been collected in ſuch a manner, as to have its properties rightly examined. In a chemical view, the effect of it, with which we are moſt concerned, is heat, which may be conſidered as fire in a ſtate of equable diffuſion, tending to equilibrium.

Heat penetrates all bodies, but cannot be fixed permanently in any ſubſtance: it expands almoſt all mineral bodies, but contracts thoſe which are organized. Bodies, which are more heated than others with which they are brought into contact, will communicate their heat, till the temperature is common. The diſpoſition of receiving and tranſmitting the heat ſo communicated, is however very different in different bodies, as may be eaſily underſtood from a glaſs rod, one end of which may be ſafely held in the hand for ſome time, while the other end of it is kept red-hot; whereas a rod of metal would not admit this. The metal is therefore ſaid to be a better conductor of heat than the glaſs, as it gives out a greater quantity. Solids are for the moſt part changed by heat into fluids, and fluids into vapours or different kinds of elaſtic airs. Thus lead is melted, or changed into a fluid ſtate, and water is converted into ſteam.

The degrees of heat commonly employed in Chemiſtry are the four following. 1ſt. The heat of boiling water; 2d. A ſand heat; 3d. A naked hot fire heat; and 4th. A ſolar heat.

Water and other fluids heated in open veſſels, and in a certain ſtate of the air, cannot acquire a higher temperature than that fixed one of the boiling point. However long the proceſs of boiling be continued, no increaſe is made, unleſs there be ſome change in the ſtate of the air. If the weight of this be increaſed, the temperature of the boiling point will alſo be increaſed, becauſe a ſtronger heat will be neceſſary to overcome the preſſure of the air, and convert the fluid into vapour.

It is a curious fact, that water, contained in a veſſel which is immerſed in boiling water, and held there for any length of time, will not boil.

The heat of boiling water being not ſufficiently ſtrong to volatilize ſeveral bodies, other degrees of heat are referred to.

The next in order is a ſand-heat. Bodies are diſtilled by immerſing the veſſel containing them in ſand. The ſand is generally put into an iron pot; and therefore any degree of heat, little ſhort of what is able to melt the iron, can be communicated to the body by means of the ſand-bath. Chemiſts employ this proceſs, alſo, upon many occaſions when a ſmall heat only is required, on account of its great convenience, and becauſe they are able to regulate the required heat accurately: ſuch heat is called a *digeſtive heat*. Should the ſtrongeſt ſand-heat be found inadequate to their purpoſe, they expoſe bodies to a naked-hot fire heat, either by caſting the bodies themſelves into a red-hot fire, or by placing the veſſels containing them in it, and keeping them ſurrounded with burning fuel. It is by the latter of theſe methods ores of metals are generally aſſayed, that is, their richneſs in metals tried; and by the former the metals are *ſmelted*, that is, melted out of their ores.

If a ſtill greater degree of heat than this be required, Chemiſts reſort to the ſolar heat; which is obtained by a large lens, or burning glaſs. This lens, collecting the ſun's rays into a ſmall ſpace, called its focus, affords the ſtrongeſt heat known in the world: it is ſaid to be capable of calcining gold, although no furnace heat has been found ſtrong enough for this purpoſe.

The inſtrument proper to ſhew the temperature of different bodies, is called a Thermometer. The Thermometer conſiſts of a ſmall glaſs tube, with a bulb or hollow ball blown at one end of it, while the glaſs of that end is in a melted ſtate. Quickſilver, well boiled, ſo as to purge it of all air bubbles, which commonly float in it, is then carefully poured in to a certain height, and the air being generally removed out of every part, the tube is then cloſed up by means of the *blow-pipe*, which is a ſmall tube uſed to direct the flame of a candle ſtrongly againſt the parts of bodies, and which, in the preſent inſtance, ſoon melts and cloſes the glaſs at the open end.

The manner of trying the temperature of a body by this inſtrument, is to place the body in contact with the bulb; the quickſilver will then riſe or fall in the tube, according to the greater or leſs degree of temperature in the body.

The degree where the quickſilver ſtands, is ſhewn by a ſcale placed beſide the tube, which has noted upon it the various degrees of temperature, from the loweſt below the freezing, to the higheſt above the boiling point; and the body is ſaid to be of the temperature where the quickſilver ſtands.

From what has been ſaid, it is manifeſt that the thermometer ſhould be very ſmall, leſt it may ſenſibly heat or cool the body it touches, and by this means alter its true temperature.

Quickſilver is choſen for thermometers in preference to every other fluid, becauſe it does not ſoil the tube; becauſe it always remains fluid (except in climates intenſely cold); and becauſe its expanſions and contractions are more uniform and regular, as alſo in very nearly accurate proportion to the degree of heat.

The chief points to be obſerved in the conſtruction of the thermometer, are: that the tube ſhould be as equal in its diameter throughout as poſſible; that the quickſilver be pure, well boiled, and free from air-bubbles; and laſtly, that the ſcale be properly adjuſted, and marked in degrees. In doing this laſt, two fixed points are choſen—the freezing point, and the point of boiling water. The former is ſettled by immerſing the thermometer in melting ſnow or ice, ſo deep, that the quickſilver in the tube may barely be viſible above its ſurface, and by carefully marking the place at which it ſtands. The latter is found out by holding the thermometer in the ſteam of boiling water, and at the ſame time, conſtantly pouring boiling water upon cloths folded round a conſiderable part of it. When theſe eſſential points are aſcertained, the whole ſcale is marked with equal degrees, the magnitude of which will be different in different thermometers, according to the diſtance between the freezing and boiling points, and according to the different conſtruction of thermometers in adjuſting the ſcale. The former of theſe is plain enough; and the latter may be ſhewn by an inſtance of two different kinds of thermometers, Reaumur's and Farenheit's. In Reaumur's ſcale the number of degrees between the freezing and boiling point is 80; the freezing point being placed at 0. In Farenheit's the number of degrees between them is 180; the freezing point being placed at 32, and the boiling point at 212: whence it is evident that, if the diſtance between thoſe points be the ſame in both, a degree of Reaumur's muſt be ſo much greater than a degree of Farenheit's, as the number 80 is leſs than the number 180, and as theſe numbers have the ſame proportion as 4 to 9, it follows that a degree of Reaumur's is ſo much greater than a degree of Farenheit's, as 9 is greater than 4; and therefore any perſon who is acquainted with the Golden Rule in

Arithmetic, can, from any given degree on Farenheit's, find the correſpondent degree upon Reaumur's, and contrariwiſe, in reducing Reaumur's to Farenheit's.

The following degrees of heat, below and above that of boiling water, with the effects produced, are given in an abridged form, from the works of Mr. Fourcroy.

Degrees of Heat below boiling Water.

The firſt degree extends from 5 to 8 of Reaumur's thermometer. This heat favours putrefaction, vegetation, and ſlow evaporation. The ſecond degree, fixed at about 15, raiſes the vinous or ſpirituous fermentation in the ſweet liquids. The third degree extends from 25 to 30: by this the acetous fermentation, or that which produces vinegar, is effected, and the juices of plants are dried up. The fourth degree diſorganizes animal ſubſtances, volatilizes their eſſential oils.

Degrees of Heat above boiling Water.

The firſt degree reddens glaſs, conſumes organized bodies, and fuſes ſulphur.

The ſecond fuſes ſoft metals, ſuch as lead, tin, biſmuth, and the fuſible glaſſes.

The third fuſes metals of a moderate hardneſs, as gold, ſilver, zinc.

The fourth degree bakes porcelain, fuſes the refractory metals, as copper, iron, cobalt, &c.

The laſt and higheſt of all is the heat of the burning glaſs, which calcines and reduces to glaſs all ſubſtances capable of theſe changes.

It has long been a queſtion among learned men, whether fire be owing to an inflammable principle, called *phlogiſton*, or not. Some maintain the exiſtence of ſuch a principle in all combuſtible bodies, and explain their combuſtion by their parting with or giving out this principle till it is conſumed; after which the body can be no longer burned, unleſs united with ſome other body on fire, whoſe phlogiſton it takes up. A great variety of experiments have been made to prove this doctrine; yet many Chemiſts have lately called it in queſtion, and endeavour to explain the phenomena, or appearances of combuſtion, merely upon the preſence of the air which they charge the former Chemiſts with having overlooked.

According to this opinion, combuſtion is nothing more than the combination of the burning body with the pure or vital air contained in the atmoſphere, which it continues to attract till it can take up no more, after which it ceaſes to burn. If this burned calx meet with a combuſtible body on fire, the latter will attract the vital air of the former, and in its turn be calcined, while the other, by the loſs of vital air, is revived, and becomes again combuſtible.

Theſe

Theſe Chemiſts further argue, that the mere loſs of phlogiſton cannot be the cauſe of combuſtion, becauſe the calx is heavier than the body uncalcined, though ſpecifically of a lighter quality; whence ſomething muſt have been gained during combuſtion. And this objection ſeems ſo unanſwerable, that a third method has been adopted, which, as it were, combines the principles of both the foregoing. By this doctrine it is maintained, that a body, during combuſtion, parts with its phlogiſton, and, at the ſame time, attracts vital air.

The nature of the preſent Work will not permit us to enter into this nice diſcuſſion, which has been mentioned only becauſe thoſe different opinions of learned men ſhould be known. It will be ſufficient to obſerve, that moſt of the phenomena have been explained upon each of theſe ſuppoſitions: but the Theory now adopted, as the moſt ſimple, is that, which explains the facts by combination with vital air. A ſimilar difference of opinion was entertained upon the cauſe of acidity which takes place in ſome bodies by combuſtion; as, for inſtance, ſulphur, which becomes vitriolic acid. And here the ſame theory prevails, viz. that the acid is a combination of ſulphur with vital air: whereas in the firſt ſyſtem, the acid was ſuppoſed to be ſulphur deprived of phlogiſton.

CHAP. III.

Of Air.

AIR is a tranſparant inviſible elaſtic fluid which ſurrounds and covers the earth for ſeveral miles above its ſurface. It is called the atmoſphere and is compoſed of a great variety of vapours and exhalations which it raiſes from the different bodies upon the ſurface of the earth.

Water which is conſtantly evaporating in large quantities muſt of courſe occupy a very conſiderable part of the atmoſphere: but there are ſcarce any bodies, mineral, vegetable, or animal which do not alſo ſupply a great portion toward its compoſition. So that we muſt be careful not to ſuppoſe it a ſimple ſubſtance: perhaps there is no other in nature in which ſo many diſſimilar ingredients are combined.

Among all theſe component parts we ſhall confine ourſelves to the three following, vital air, fixed air, and inflammable air.

Vital air is that portion of the atmoſphere which is indipenſibly neceſſary to ſupport the reſpiration or breathing of animals and the burning of combuſtible bodies. It is for the firſt of theſe reaſons ſometimes called *eminently reſpirable air*, and for the ſecond *empyreal or fire air.*

Dr. Prieſtly gave it the name of *dephlogiſticated air*, as not containing phlogiſton, a name very proper to deſcribe it, if the exiſtence of that principle be admitted; for certainly there is no greater oppoſition between any two ſubſtances in nature than between vital air and phlogiſton, as may be eaſily collected from the few obſervations at the cloſe of the laſt chapter. This air compoſes about one forth part of our atmoſphere.

That vital air eminently contributes to the reſpiration of animals appears from hence. If a ſmall animal be incloſed in a veſſel containing vital air, he will live much longer than in atmoſpheric air or any of its other component parts. The ſame thing appears likewiſe from another fact; that ſuch perſons as happen to breath this air, feel their ſpirits become more gay and lively; and that vital air aſſiſts the combuſtion of bodies is plain from the experiment of immerſing a lighted taper in a veſſel of this air, or from burning any combuſtible body together with nitre or ſalt-petre which abounds in vital air: in both caſes the flame is bright and luminous, and the heat increaſed. Vital air indeed is ſo neceſſary to both purpoſes abovementioned, that when it is abſorbed either in the proceſs of combuſtion or reſpiration, the remaining part of the air is unfit for both; candles are extinguiſhed and animals die in it.

A certain quantity of atmoſpheric air is diminiſhed in bulk about one fifth, from bodies being burned in it by charcoal: the remaining air is called *phlogiſticated air*, *mephitic gas*, &c.

Various ſubſtances as nitre, red-lead, alum, mangancſe and others afford vital air by heat. Green vegetable matters which are found in water emit it when they are expoſed to the light of the ſun, and the leaves of plants in like circumſtances afford it. Whence it is manifeſt that abundant proviſion has been made by the Deity for reſtoring the purity of the air which is continually injured by combuſtion, reſpiration, fermentation and other proceſſes. Vegetables which ſupply ſuch abundance of vital air as we have juſt obſerved, yet do not flouriſh ſo well in this as in a more impure air. And thus the vegetable and animal world reciprocally adminiſter to each others advantage; animals exhaling thoſe impurities which contribute to the health and growth of vegetables, while theſe in their turn diſpenſe that pure vital air ſo indiſpenſible to the health and life of animals.

Fixed air is another kind, widely differing in its properties from the former. It deſtroys animal life, extinguiſhes flame, and prevents combuſtion. This air is frequently found in pits and caverns under ground, and forms what is called the choak damp of mines: hence it is called alſo mephitic air. It is heavier than atmoſpheric air in the proportion of about 3 to 2: when put together in the ſame veſſel it therefore ſinks to the bottom, the common air floating above. The preſence of this air is almoſt univerſal in the animal and vegetable kingdoms. Fermenting liquors diſengage it in large quantity, and mineral waters ſhew its exiſtence in them by the ſparkling which they exhibit on being poured out. Chalk, limeſtone, and other calcareous ſubſtances owe near one half their weight to this air, which may be extricated from them by the application of heat, or by acids. Certain ſalts, called Alkaline, abound with it in an equal degree. Water attracts it ſtrongly, and abſorbs more than its own bulk, reſembling in this ſtate ſome ſpa waters: the colder the water is, and the more it is agitated, the more air will it imbibe.

Fixed air is by ſome chemiſts ſuppoſed to conſiſt of the inflammable matter of charcoal combined with vital air: for if this ſubſtance be burned together with vital air in a cloſe veſſel, the reſult is found to be fixed air. Charcoal is a well known ſubſtance, procured by the imperfect combuſtion of vegetable matters, as wood: which is piled up into a heap ſmall towards the top, and covered with earth or clay; leaving a few air holes, which are cloſed when the maſs is lighted. From this proceſs much inflammable matter remains behind, which they call phlogiſton, carbon, and which is of the ſame nature with the diamond; as will be ſhewn hereafter. In the new theory, the charcoal is ſaid not to be fully ſaturated with vital air, and therefore a further combination takes place, which is the ſame as combuſtion.

Of late, fixed air has been claſſed by writers among the acids, becauſe it is found to poſſeſs their chemical properties: and it is ſometimes called *aerial acid* as having the phyſical properties of air: ſometies *chalky acid*, from its being contained in large quantities in chalk: ſometimes *carbonic acid*, from its being the reſult of burning charcoal. It combines with various ſubſtances, compoſing with them different kinds of what are called neutral ſalts; ſome of which will be mentioned in other places. A ſolution of lime in water is a teſt of its preſence: for as ſoon as fixed air and this fluid are mixed, a white cloud is ſeparated, owing to the ſtrong affinity between the lime and the air.

Fixed air has the property of preſerving animal ſubſtances from putrefaction, and is often preſcribed in putrid fevers. It is alſo ſometimes reſpired along with common air for diſorders in the lungs.

The third kind of air which remains to be noticed is called *inflammable air*; becauſe it takes fire with the ſmalleſt ſpark, provided it be in contact with vital air: but when it is unmixed with any other, or is in contact with fixed air, it cannot be kindled. This air poſſeſſes a very great power of expanſion: by which property it is enabled to bring every particle of itſelf into contact with vital air, ſo that a ſingle ſpark runs through the whole in a moment,

ment, and an exploſion follows. Fatal inſtances of this kind ſometimes occur in mines, where this air is often found collected in conſiderable quantity, and where the uſe of candles is neceſſary. There is one part of the Duke of Bridgewaters works, where it abounds. On one accaſion not very long ſince it was, through neglect, ſuffered to collect, by being confined during the courſe of a night: in that ſtate it inſtantly took fire at the approach of a candle, and did great damage by its exploſion.

Inflammable air is extremely light ſo as not to weigh a tenth part ſo heavy as common air. By means of this property it has been employed in the conſtruction of balloons: which being filled with this air, not only can eaſily aſcend in atmoſpheric air, but are alſo capable of carrying up with them conſiderable weights. The air employed for this purpoſe is for the moſt part obtained, by diſſolving filings of iron or zinc in vitriolic acid diluted with water, theſe and other metallic ſubſtances affording the pureſt inflammable air. It may be alſo procured from all vegetable and animal ſubſtances by diſtillation, and alſo by putrefaction. Charcoal yields it by the former proceſs, if diſtilled in conjunction with water, but not otherwiſe. Stagnant waters, whoſe bottoms are covered with putrid vegetable matters, ſwampy grounds, cellars, &c. &c. yield heavy inflammable air, that is, this air mixed with carbon.

If in a ſtrong cloſe veſſel inflammable and vital air be encloſed together, and if by means of a wire running through the veſſel the electric ſpark be paſſed through the mixture, the airs will vaniſh, if they be pure, and water will be produced. This important experiment was firſt made by Mr. Cavendiſh, and afterwards by Mr. Lavoiſier and others; as will be ſhewn more particularly hereafter.

Thunder ſhowers may from this receive an explanation. For when lightning, which has been proved by Dr. Franklin to be electric fire diſengaged by the colliſion of clouds, paſſes through the air, it meets with thoſe two component parts of it, and rain generally ſucceeds. Another and perhaps ſtill more adequate explanation of this will appear in next chapter.

The method of combining different airs or elaſtic fluids is one of the moſt curious parts of experimental chemiſtry, for the knowledge of which we are chiefly indebted to the great ingenuity of Dr. Prieſtly; but the apparatus being rather too nice and difficult for younger ſtudents, a few general remarks will enable them to comprehend more eaſily that courſe of experiments on ſome future occaſion.

If a glaſs vial or other veſſel be filled with water, and be inverted into another veſſel of water, the mouth being ſtopped before inverſion, it will remain full although the ſtopper be removed.

This is owing to the preſſure of the air which is able to ſupport a column of water to the height of 33 feet in the ſame manner as it ſupports quick-ſilver in the barometer at the height of about 30 inches. Now if any fluid reſembling air in lightneſs and elaſticity be ſuffered to enter this vial, it will by its lightneſs riſe to the upper part and by its elaſticity force the water down. By continuing the proceſs all the water may be diſplaced and the whole vial be occupied by the elaſtic air.

Let then the veſſel into which the inverted vial is immerſed be a tub with a ſhelf fixed in it, and let the water in the tub riſe about one inch above the ſhelf. In this ſtate of things let a glaſs tube be provided bent in ſuch a manner as to paſs over the ſide of the tub and under the water, until one end of it communicates with the mouth of the vial while the other end of it may be applied to the veſſel from which the required air is to be extricated.

For inſtance, to make the experiment juſt now mentioned of paſſing the electric ſpark through vital and inflammable air. Let nitre be heated in a cloſe veſſel into which one end of the bent tube may be inſerted, while the other end is at the mouth of the vial. Vital air will be diſengaged from the nitre and paſſing through the tube will occupy the upper part of the vial after having driven the water down.

When a ſufficient quantity of the vital air is obtained, ſuppoſe half the vial full, then let the tube be inſerted into another cloſe veſſel, containing the filings of iron and diluted acid of vitriol. Theſe ſubſtances will ſet free inflammable air, which may be paſſed through the tube until the whole of the water is driven from the vial.

The vial is thus filled with the two airs, and by cloſing its mouth and well ſtopping it, the vial may be placed upright and the electric ſpark paſſed through it by means of a metallic wire fixed in the upper end of the vial. Should the required air unite with water, it will be neceſſary to employ quick-ſilver or ſome other fluid with which it will not unite, for the purpoſe of obtaining it. But it is ſometimes found convenient to impregnate water with ſome of thoſe airs, as for inſtance fixed air, which may be done in the following manner:

An apparatus conſiſting of three glaſs veſſels placed one above another, is provided. The middle veſſel, which is to contain the water, has two necks, one of which is cloſely inſerted into the neck of the loweſt, and has a valve ſo contrived as to let the air paſs up, yet prevent the water from flowing down: into the other neck is fitted the neck of the higheſt veſſel which is a long tube reaching near half way into the middle veſſel, and at the top of the higheſt is an orifice cloſed by a conical glaſs ſtopper which can be raiſed by any reſiſtance from within. The middle veſſel being new filled with water, and pieces of chalk with ſome acid being introduced into the loweſt veſſel through a ſtop cock, the diſengaged air ruſhes up through the valves to the top of the middle veſſel, where by its elaſtic force it preſſes down the water and forces it up through the long tube into the upper veſſel, diſplacing the common air, ſome of which eſcapes through the ſtopper. This proceſs continues, till the water in the middle veſſel ſinks as low as the mouth of the long tube: in which ſtate of things the fixed air gets freely into contact with the water in the higheſt as well as in the middle veſſel, and of courſe impregnates the whole. A ſtop cock in the middle veſſel lets it off as convenient. This apparatus is by Nooth.

As the atmoſphere conſiſts of different vapours, it is probable that the lighteſt of theſe, ſuch as inflammable air, form ſtrata which float upon common air. Mr. Lavoiſier ſeems to have thought this to be the caſe, and that the phenomena of the aurora borealis and other fiery meteors were owing to it. But even ſhould this not be ſtrictly ſo, theſe phenomena may be explained by ſuppoſing a conſiderable accumulation of inflammable air in different parts of the atmoſphere, meeting with electric fire, which often abounds in thoſe regions.

CHAP. IV.

Of Water.

WATER is a tranſparent fluid ſubſtance, which covers a great portion of our earth, in ſeas, rivers, lakes, &c.: it is beſide found in almoſt all the bodies in nature. Even thoſe ſubſtances which ſeem to poſſeſs little or none of it, are yet found to contain it in large quantities. Vegetables, eſpecially thoſe of a ſucculent or juicy kind, abound with it. A freſh pumkin, weighing 200 ounces, being cut into ſlices and dried in the ſun, was found to loſe in nine days 190 ounces; and, when the remaining ten were burned to aſhes, they did not yield one ounce; ſo that almoſt the whole of this fruit conſiſts of water and air. Art has not been able to combine this fluid with ſeveral ſubſtances with which Nature has united it.

Water is one of the moſt univerſal agents in nature. Beſide a great multitude of other effects upon, beneath, and above the ſurface of the earth, it ſerves to give riſe to ſprings and fountains, to purify the air, to fertilize the earth, to ſuſtain all vegetable and animal life, &c. &c.

It is likewiſe under different forms one of the moſt uſeful inſtruments in works of art, eſpecially where machinery is employed, that requires very great force and power.

There is a queſtion among learned men, as to the nature of water; ſome holding it to be unchangeable, while others contend that it may be changed into other ſubſtances, particularly into earth. Without entering at large into this controverſy, the mention of a few facts will be ſufficient. Boerhave is ſaid to have diſtilled water five hundred times, yet without any ſenſible alteration. On the other hand, Boyle mentions the report of an ingenious chemiſt of unſuſpected credit to be, that, after two hundred diſtillations, water afforded three parts out of four of earth, and that in each ſubſequent diſtillation the earth was afforded more copiouſly to all appearance.

Lavoiſier weighed the glaſs veſſel, and found it lighter; whence he concluded that the earth belonged to the veſſel. On the other hand, the veſſel does not loſe ſo much as the weight of the earth obtained, and this earth had entirely different properties from thoſe of glaſs. Margraaf is of opinion that water is tranſmutable into earth; but, upon the whole, this matter is not as yet aſcertained.

Water appears in three different ſtates, ſolid, fluid, and vapoury. In the ſolid ſtate it aſſumes the forms of ſnow, hail, and ice. Snow and hail are produced by the condenſation of water diffuſed through the different regions of the atmoſphere in different ſtates of aggregation: hail in the lower regions, by the condenſation of large drops of water in the fluid ſtate; ſnow in the higher, by the cryſtallization of very minute particles, or of vapour. Hence it is, that hail is not found about the polar regions, becauſe water does not exiſt there in the liquid ſtate. Snow may be produced by the admiſſion of intenſely cold air into a warm apartment. An inſtance is recorded of a ball-room in Ruſſia, the window of which being opened, the humid vapour within was converted into ſnow, and fell in this form upon all preſent. Snow and hail are leſs tranſparent than ice, probably from a greater proportion of air mixing in their formation and compoſition, which rendering their denſity leſs uniform, ſo far injures their tranſparency. And, for the ſame reaſon, hail ſometimes approaches to ice in this reſpect more than ſnow. Although the freezing of water into ice be occaſioned by cold, yet is a ſenſible heat ſometimes produced in the act of its becoming ſolid; for a thermometer plunged in water that is freezing, ſtands at the freezing point, although another in the open air may at the ſame time ſtand below the freezing point.

If a piece of ice, whoſe temperature is conſiderably below that of the freezing point, be taken into a warm place, its temperature will encreaſe till it reaches the freezing point, at which it will remain till the ice becomes fluid, when it will begin again to riſe. During the whole time of the temperature remaining ſtationary, the ice being colder than the ſurrounding air, muſt receive an acceſſion of heat; and yet no ſenſible encreaſe of temperature appears. The heat ſo received is therefore called *latent heat*, and is thought to be employed in rendering the ice convertible into water by chemical combination. The degree of heat neceſſary for this purpoſe alone is found capable of raiſing the temperature of water from the freezing point, viz. 32° of Farenheit ſo high as 140′.

The converſe of what has been juſt mentioned, takes place with warm water expoſed to cold below the freezing point. Its temperature at firſt falls down to that point; where it remains ſtationary for ſome time, or perhaps riſes, till the water becomes ice, when it begins again to fall. Water, which is expanded by heat, contracts its dimenſions in cooling, till the temperature falls to about eight degrees above the freezing point; at which time it again expands, and, when in the form of ice, becomes more bulky than in its fluid ſtate, ſo as to burſt the veſſels in which it is formed. This may be owing to the diſengagement of air or heat, or to a new arrangement of particles by cryſtallization. The production of ice is aſſiſted by air and gentle motion.

The permanent ſolidity of ice in very cold countries is ſurprizing. We read of a large houſe in Ruſſia, built and furniſhed with ice, and beautifully illuminated; and of artillery made of ice, diſcharging balls of conſiderable weight with effect.

Water, in its uſual ſtate, contains much earthy and other matters, which render it quite unfit, in this ſtate, for chemical experiments. It ſhould be always diſtilled for ſuch purpoſes in cloſe veſſels, and thus, with a heat below 212°, the pure water comes over into the receiver, while the earth remains behind. Diſtilled water, however, is not ſo fit for drinking, being inſipid, and cauſing a ſenſation of weight in the ſtomach. Theſe inconveniences may be removed by agitating it in the air, which gives it a more briſk and lively taſte, and renders it more wholeſome.

If water be heated to 212° of Farenheit's thermometer, it boils, and is converted into ſteam; in which ſtate it is expanded ſo as to occupy 1400 times as much ſpace as before. Steam is wonderfully elaſtic, and produces terrible exploſions while it is confined. By means of this great elaſtic force, it is employed in mechanics with much advantage, in putting very large bodies in motion. The machine uſed for the purpoſe is hence called the Steam Engine. In manufactories, where furnaces are kept conſtantly boiling for one part of the work, a power is thus obtained, without further expence, to work the machinery which may be required in other parts.

The elaſtic force of ſteam is clearly demonſtrated, by including water in a ſtrong metallic globe or veſſel called the Eolipile, which has but one very ſmall opening. When the water boils, the ſteam iſſues out with great violence, and will act upon a fire like a bellows, by driving the air ſtrongly before it. If the metal veſſel be quite cloſed, the water may be nearly heated red-hot, and, upon opening the veſſel in any part, ſteam ſuddenly ruſhes out, the temperature of it immediately falling to 212°.

If water be ſuſpected to be in an impure ſtate from being combined with noxious matters, being too long confined from acceſs of air or any other cauſes, it may be purified in the following ways: by agitation in open air, which ſerves to give it a briſk taſte, and favours the depoſition of improper matters: by boiling, which diſengages the noxious airs with which it may be loaded: and by filtration, or ſtraining through porous ſtones, or other ſubſtances, which let the water paſs through, while the impure and foreign matters remain behind. Water is ſometimes hard, ſo as not to diſſolve ſoap: this is owing to its containing ſome acid, which decompoſes the ſoap. It may be corrected by adding ſome potaſh, which ſeparates this acid from the earth to which it was united. Filtering, alſo, is in ſome degree a remedy; for the acid, being combined with the earth, will not paſs through.—With the ſubjects of this and the foregoing chapter, may be properly connected a few remarks upon the ſuſpenſion of water in air.

The explanation of this curious and intereſting effect has been attempted in different ways; but the generally received opinion now is, that it is owing to ſolution, like the diſſolving of ſalts in water. The moſt certain mark of ſolution in water or other clear fluids, we know is, that the tranſparency of the ſolvent ſtill remains; whereas if there be no ſolution, but merely a ſuſpenſion or mixture, the tranſparency is loſt. We may therefore fairly conclude, that the water, which is raiſed into the air, is held there in a ſtate of ſolution, for otherwiſe the tranſparency of the air would not remain.

Salts are, for the moſt part, more quickly diſſolved in hot water than in cold. In the ſame manner, water is more ſpeedily diſſolved by hot air than by cold. Miſts and dews are more ſpeedily dried up in the ſun than in the ſhade.

If water be ſaturated with a ſalt at a certain temperature, it will hold that ſalt in ſolution ſo long as that temperature is not diminiſhed; but, as the water cools, ſome of the ſalt will ſeparate, and fall to the bottom. We may obſerve a ſimilar effect in the caſe of water and air: while the air continues hot, the ſolution is complete; when it cools, the water falls to the earth. Thus, in the morning at ſun-riſe, and in the evening at ſun-ſetting, the air being cold, miſts and dews are obſerved to hang over the ground, which the ſun diſſipates in ſolution, while he is above the horizon, and his heat ſtrong.

Miſts and dews are generally greateſt, when the difference of heat in the day and night time is greateſt; becauſe in this caſe more water will be raiſed by the heat, and more falls by reaſon of the cold; ſo that both cauſes concur to increaſe the quantity of the dews. In cold weather the breath of animals becomes viſible, becauſe there is not ſufficient heat to diſſolve the moiſture which is exhaled from the lungs.

Theſe and other facts ſeem to make this manner of explaining the matter highly probable. The ſubject is moſt ably and fully illuſtrated in the Philoſophical Eſſays of the Rev. Dr. Hamilton, Biſhop of Oſſory.

The quantity of water contained in the air is very conſiderable, ſo that were all that is diſſolved in it precipitated, there would probably be enough to cover the earth's entire ſurface, not only to the height of thirty-two feet, *i. e.* the height of a column of water equiponderant to a column of the atmoſphere (as ſome have ſuppoſed), but to an indefinite height. The ſuppoſition that thirty-two feet was the limited height, was founded on the hypotheſis, that the preſſure of the air was intimately connected with the quantity of water contained in it: but daily obſervations ſhew that this opinion is unfounded. During a long ſummer's drought there is a continued abſorption of water into the air; therefore, on this hypotheſis the barometer ſhould be continually riſing; but, on the contrary, it is found to be ſtationary during the whole time, at thirty inches, or a little more: and, what is ſtill more extraordinary, when the drought is about to have an end, while the air yet contains the whole quantity of water it had abſorbed, and has not parted with a ſingle drop, it becomes ſuddenly lighter, and the mercury will ſink perhaps an inch. And after the atmoſphere has been diſcharging for a number of days a fluid 800 times heavier than itſelf, inſtead of being lightened by the diſcharge, it becomes heavier, and even ſpecifically heavier than it was before.

From theſe remarks, and from the large quantities of water proved to exiſt at the greateſt depths below the ſurface, it is evident, that the ſyſtem of nature contained ample materials for effecting the univerſal deluge. And if (as many have with great probability maintained) the atmoſphere owes its ſolvent power, or a great ſhare of it, to electricity, a conjecture, perhaps not unreaſonable, may be formed, of the manner in which the deluge was produced. We are aſſured by undeniable obſervations, that electricity is able to ſwell up the water on the ſurface of the earth; the agitation of the ſea in earthquakes is a proof of this; for, at the ſame time, there is a diſcharge of a vaſt quantity of electric matter into the air, and as ſoon as this happens, all becomes quiet on the ſurface of the earth. From a multitude of obſervations it appears alſo, that there is at all times a paſſage of electric matter from the atmoſphere into the earth, and vice verſa from the earth into the atmoſphere. There is no abſurdity in ſuppoſing that the Deity influenced the action of the natural powers, in ſuch a manner, that, for forty days and nights, the electric matter contained in the atmoſphere ſhould deſcend into the bowels of the earth; the conſequence would be, "the breaking up of the fountains of the deep, "and opening the windows of heaven." The water contained in the atmoſphere being left without ſupport, would deſcend in impetuous rains, while the waters of the ocean, thoſe from which the fountains originate, and thoſe contained in the ſolid earth itſelf, would riſe from the very centre, and meet the waters which deſcended from above. Thus the breaking up of the fountains of the deep, and the opening the windows of heaven, would accompany each other, as Moſes tells us they actually did; for, according to him, both happened on the ſame day. The abatement of the waters would enſue on the aſcent of the electric fluid to where it was before: the atmoſphere would then abſorb the water as formerly; that which had aſcended through the earth would again ſubſide, and thus every thing would return to its former ſtate.

It has been ſaid, that the ſuſpenſion of water in air is either altogether, or for the moſt part, owing to electricity. It is certain that evaporation is promoted by electrifying the fluid to be evaporated. But if the principle be even partially admitted, it affords another ſolution of the phenomenon of a thunder-ſtorm, different from that mentioned in the laſt chapter, though indeed both may concur in producing the effect. When thunder clouds, loaded with water, meet each other, and a diſcharge of electric fire enſues, the air ſuddenly loſes much of the power by which it had held the water ſuſpended; of courſe rain muſt fall as ſuddenly, and in great abundance, as we know it does.

The air not only raiſes and diſſolves water, but likewiſe the matters perſpired by animals and vegetables. If theſe and other exhalations be in great abundance, the air of courſe becomes foul and noxious. In fenny countries, or places overflowed by water, where ſlime is depoſited, conſiſting of decayed vegetables, and other putreſcent bodies, the climate is generally unhealthy, eſpecially if theſe cauſes be accompanied by a burning ſun.

CHAP. V.

Of EARTH: *and firſt of* SILICEOUS *and* ARGILLACEOUS EARTHS.

BY the name of earth is generally underſtood every hard, dry, inſipid ſubſtance that makes part of our globe. Of theſe ſubſtances there are many different kinds, which Chemiſts have divided into a great variety of orders and claſſes: but we ſhall conſider them under the following heads which are moſt neceſſary to be known, Siliceous, Argillaceous, Calcareous, which may likewiſe be called flint, clay and lime.

It is obvious that the ſubſtances here mentioned include ſtones as well as what is vulgarly called earth, for ſtones are reckoned by Chemiſts to be nothing elſe than harder maſſes of earth.

Siliceous, which is alſo called vitreſcent earth or flint, is found in conſiderable quantity in thoſe bodies which ſtrike fire with ſteel. Like all other ſimple earths they are not combuſtible nor fuſible unleſs when they are mixed with other ſubſtances, in which caſe they are melted into glaſs or give a ſtronger conſiſtency to thoſe ſubſtances.

ſtances. Both theſe things will be ſhewn in other places.

The principal kinds of this earth are firſt, the rock chryſtal; ſecondly vitreous precious ſtones, ſuch as the topaz, the hyacinth, the ſapphire, emerald ruby and amethyſt; all theſe precious ſtones are found by analyſis to contain in various proportions the three kinds of earth here mentioned together with a ſmall quantity of iron and other metallic ſubſtances: thirdly quartz containing under it flint, agate, jaſper, petrifactions, ſpars, free-ſtone and ſand.

Of rock chryſtal the heat of common furnaces alters neither the tranſparency nor hardneſs, ſo that this ſtone appears moſt free from mixture. The precious ſtones are more alterable by fire, and quartz with its ſeveral kinds is reduced by it into a white opake earth. Free-ſtone is more opake and much leſs hard than agate or flint; it is found in large maſſes more or leſs compact and of a more or leſs fine grain.

That ſpecies of ſiliceous earth, which is called ſand, is of numberleſs advantages to us, letting the water paſs between its grains for the ſupply of wells and fountains, and affording a more regular and conſtant ſupply of equable moiſture. It is alſo very uſeful in preventing other earths from becoming too hard, by ſeparating thoſe parts which are apt to be too much bound together, and thus enables them to receive thoſe nouriſhing juices which make them fruitful. In works of art it ſerves to ſtrengthen thoſe cements made uſe of in building; is indiſpenſible in the beautiful art of pottery; forms a large part of the manufacture of glaſs, and ſerves many other valuable purpoſes. If pure ſiliceous earth be required, it will be obtained by diſſolving it in an Alkali or ſtrong potaſh, which will thus ſeparate it from its impurities, and then by adding an acid to the ſolution which uniting with the alkali will precipitate the ſiliceous earth. If flint be employed here the ſolution is called liquors of flints.

Argillaceous earth or clay is a fat flexible ſubſtance that adheres to the tongue, is of great tenacity when wetted with water, and grows hard and contracted by the fire. Upon this principle Mr. Wedgwood made a brick of known dimenſions a thermometer. If this earth be once baked it is impoſſible by any proceſs of pulverizing and kneading with water to make it ſerve the ſame uſe again: all this tenacity is loſt beyond recovery, except by diſſolving it in an acid and by precipitation.

This earth makes a very conſiderable part in all ſpecies of pottery, and as it is found of different purity in different places, a great difference will of courſe be found in wares made in thoſe places; the whiteſt clays are eſteemed the pureſt.

Fine pottery is manufactured ſomewhat in the following manner. Very fine tobacco pipe clay is waſhed and beaten a good while in water, by which proceſs the finer parts of the clay remain a good while ſuſpended, and the groſſer impurities fall to the bottom. The thick fluid is further purified by ſtraining it through hair ſieves of different degrees of fineneſs. Powdered flint which has been properly calcined and ground is alſo prepared by a ſimilar proceſs, ſo as to be of the ſame thickneſs with the former. The thickened liquids are then to be well mixed in various proportions for different wares and are left to ſet. This mixture is afterwards dried in a kiln, and being beaten into a proper temper is taken to the wheel, which is placed in an horizontal or flat poſition and the paſte being laid upon it while the wheel turns briſkly round, is formed into ſhape by the hands of the artiſt.

This ware gradually dried is then put into a furnace and placed in caſes piled over each other in the dome: and when brought to a proper temper for receiving the glaze which is in about 48 hours, ſalt is thrown into the furnace and inſtantly converted into vapour; which vapour circulating through the furnace enters the caſes through holes in their ſides and forms upon the ſurface of the ware a glaſſy coat called its glaze: this is probably owing to the combination of the alkali of the ſalt with the ſiliceous earth.

There is another kind of glaze which is more beautiful than the former, it conſiſts of a large portion of white lead, with about a fourth part of ground flint, and a ſmall portion of flint-glaſs pounded, and mixed together and fuſed. The ware when baked is dipped into this liquid glaze, and ſuddenly taken out, when the glaze is imbibed and the ware becomes dry. The ware is then expoſed a ſecond time to the fire, by which means the glaze that was imbibed is melted, and forms a thin glaſſy coat upon its ſurface, which is more or leſs yellow according to the quanitty of lead uſed.

Our wares are not inferior to the porcelaine of China either in the materials of their compoſition, or in the art of manufacturing.

The materials of Eaſtern porcelaine are 1ſt. A vitreſcent ſubſtance reduced to very fine powder called *petunſe* or feltſpar. 2d. An unctuous clay called *Kaolin*. 3d. A varniſh compoſed of the fineſt particles of a ſoapy earth, as ſteatite. The Chineſe petunſe is fuſible in a ſtrong degree of heat without being mixed with other ſubſtances: which probably gives to China that fine tranſparency above our ware. The painting on porcelaine is put on before the glazing: the colours burnt into the ware by which they become permanent and laſting. But of theſe when we ſpeak of enamelling. The principal kinds of argillaceous earths are ſoft and ductile clays which are thoſe moſtly uſed in pottery as above: dry, friable, or crumbling clays, ſuch as fuller's earth, which is of great uſe in cleaning woollen cloth, and imbibing the oil and greaſe employed in working it: Steatites, Talc and Aſbeſtus or Amianthus, this laſt kind of ſtone is formed of a ſort of fibres placed parallel at the ſide of one another. The ancients uſed to ſpin them and made a cloth called incombuſtible linnen, in which they burned the dead and were enabled to collect the aſhes unmixed. With a very ſtrong fire however Aſbeſtus is fuſed into glaſs. Marle is by ſome reckoned among the argillaceous earths, and by others among the calcareous.

It is difficult to aſcertain points of this kind when a ſubſtance partakes of the nature of two others. It is the ſame with ſpars which by ſome are ranked among the argillaceous and by others among the ſiliceous earths: but ſpar is a general name applied to chryſtallized earth of whatever ſpecies.

CHAP. VI.

Of CALCAREOUS *and ſome* COMPOUND EARTHS.

CALCAREOUS earth is an earth which contains a large quantity of fixed air and may be diſcovered by pouring a little acid on the earth or ſtone to be tried for if it be of this kind, it will froth and bubble at the eſcape of the air.

It is generally found in chalk, marble, ſpars, plaſter-ſtones, bones and ſhells: and likewiſe in ſtones of a whitiſh grey or blueiſh colour. When any of theſe is calcined by burning, the calx is called *quicklime*. It changes the ſyrup of violets to green, and has a ſharp corroding taſte. During the calcination the ſtone has loſt near half its weight, but recovers part of this again by expoſure to the air, attracting from it very ſtrongly both fixed air and water.

Water added to quick-lime produces conſiderable heat attended with a crackling noiſe: the quick-lime gradually falls and when ſaturated with the water is converted into ſlacked lime. In burning lime care ſhould be taken that the heat be neither too weak nor too violent: if it be too weak, much of the ſtone will remain unburnt; if too ſtrong the lime will be vitrified or converted into a kind of glaſs.

That this will be the caſe is evident from the ſcum or ſlag of an iron furnace in which lime has been uſed as is ſhewn hereafter. It is alſo neceſſary for *pot-kilns* that the ſtone be broken ſmall, that the heat may more eaſily penetrate every part, and calcine the whole; otherwiſe the outward ſurface of the ſtone will be burned while the heart is untouched. In arched-kilns however this is not requiſite, for in them large maſſes of limeſtone are completely burned without breaking.

A mixture of calcareous and argillaceous earths is converted to glaſs by a degree of heat which will not vitrify either of them alone as appears by the following experiment. In the middle of a crucible containing equal weights of powdered chalk and clay, let a lump of each be placed ſo as to be ſeparate from each other, and ſurrounded on all ſides by the mixture, when the mixture is quite reduced to glaſs; upon breaking this both ſolid lumps are found without having ſuffered any change. And hence it is that bricks and tiles which often contain both clay and calcareous earth do not ſtand the fire without being fuſed.

The encreaſe of weight in quick-lime expoſed to the air makes it important at what time it is purchaſed if ſold by weight, and alſo at what time it is conveyed from one place to another, the delay of doing this, being attended with a greater expenſe of labour. It is worthy of notice too that lime which has once received its greateſt increaſe does not afterwards loſe let the ſeaſon be what it may; and therefore whatever matter it has attracted from the air is of a laſting nature, not ſubject to evaporate but beſtowing upon the ſoil a very conſiderable increaſe of matter, and this, as it will hereafter appear, of the moſt valuable kind for ſupporting vegetation.

Limeſtone calcined by fire loſes about the ſame weight as if calcined by acids and therefore it may be preſumed that the matter loſt in both caſes is the ſame.

Now experiments ſhew the matter loſt in the calcination by acids or the ſolution in acids to be an air agreeing in all its properties with fixed air, and this calcined earth may be perfectly reſtored to its firſt ſtate, by pouring into its ſolution another ſolution of ſtrong alkali, which contains fixed air; a double elective attraction then takes place, for the acid unites with the alkali and the calcareous earth with the fixed air. This latter ſubſtance is found to be of of the ſame weight and nature with the crude limeſtone. And in the ſame manner if to quick-lime calcined by fire, ſhould be reſtored the whole fixed air it had loſt, the reſult would be a ſubſtance agreeing in all its properties with crude limeſtone. Hence it ſhould appear that the burning of limeſtone has merely the effect of reducing it to powder; ſo far at leaſt as depends upon its conſtituent part fixed air, provided the lime be long expoſed to the atmoſphere. Water diſolves about one ſeven-hundreth part of its weight of lime, this ſolution is called *lime-water*.

If lime water be expoſed to the open air, a cruſt will ſoon be formed on its ſurface called cream of lime; which being broken falls to the bottom and a new one is formed until at length the whole lime is ſeparated. This cruſt is chalk formed by lime attracting the fixed air from the atmoſphere.

If lime be mixed with ſand it forms a hard matter called cement of mortar which ſtrengthens and conſolidates by length of time. In making this mixture as little water ſhould be uſed as is barely ſufficient to ſlake the lime and blend them both together. This is thought to have been the proceſs of the ancients whoſe cement is almoſt as hard as ſtone. Barytes or ponderous earth, and magneſia, which are ſeldom or never found pure, but mixed with ſulphuric acid, reſemble calcareous earth in many of their properties, ſo as by ſome chemiſts to be ranked in the ſame claſs. We ſhall occaſionally take notice of them in their combination with other ſubſtances.

To this account of theſe ſimple earths we may here ſubjoin a ſhort account of ſome compound earths produced by the action of water or fire or ſome other natural cauſe of their compoſition.

Ochres are thought to be the products of water. They are more difficult to be diffuſed through water than clays, they are friable or crumbling and ſtain the fingers: and are coloured by metallic ſubſtances. They are of different colours as yellow, red, green or brown and are uſed in paints.

The azure ſtone or Lapis Lazuli is a ſtone of a fine deep blue mixed with yellow veins like gold and contains iron; this ſtone is much eſteemed for its uſe in preparing the paint called ultramarine which is the moſt beautiful blue obtained by painters.

Granite is formed of quartz, felt, ſparkling ſpar and mica. It ſtrikes fire with ſteel on account of the quartz and ſpar. It breaks in an irregular coarſe grain but is capable of receiving a poliſh. Some kinds are altered by the air.

Porphyry is a ſtone thick ſet with ſtains upon a red or ſome other coloured ground. It differs from the granite in its greater hardneſs and finer poliſh. This ſtone is fuſible and gives a coloured glaſs.

Pumice ſtone is a combination of different ſubſtances fuſed by the fire of volcanoes; it reſembles a ſponge in texture and is ſo light as to float upon the ſurface of water. This ſtone is made uſe of by artiſans in their ſeveral trades.

Puzzolane earth, ſo called from the city of Puzzoli, where it was aciently uſed is an earth charged with iron and like the former is produced by the action of ſubterraneous fires. This earth is very uſeful in making a kind of mortar which hardens in the air: and alſo in the conſtruction of buildings under water for when mixed with quick-lime it hardens there into a ſolid ſtone.

Lavas are ſubſtances fuſed and partly vitrified by the volcanoes. They are thrown out on the ſides of mountains like burning rivers, flowing to a great diſtance and deſtroying every thing in their courſe: they take ſeveral years to cool. The colour of *lava* is black or dark grey for the moſt part. Its ſubſtance conſiſts of about one tenth part of iron; one fourth or more of clay, and the reſt flint, and is capable of ſtriking fire with ſteel.

Baſaltes is a ſtrong ſubſtance of a dark appearance, of conſiderable weight and ſtrikes fire with ſteel, it contains iron. Baſaltes is formed in pillars whoſe ſhafts are compoſed of parts moſt nicely fitted to each other by a concave furface and adapted to a convex ſurface in the other. There are great promontories found that conſiſt of ranges of thoſe pillars diſpoſed one above the other from the baſe which is laid in the ſea to the top of the promontory.

A remarkable one of this kind is the Giant's Cauſeway in Ireland on the coaſt of Antrim.

The Baſaltes is by ſome thought to be the effect of volcanoes, this opinion is ſupported by the late Dr. William Hamilton in an ingenious eſſay upon the ſubject, but ſeems notwithſtanding to require further proof.

CHAP. VII.

Of the Uſe and Application of the different EARTHS *in Agriculture.*

THE ſeveral ſpecies of primitive earths conſtitute the baſis and moſt obvious inſtrument of vegetation, but are not ſufficient to maintain it when they are taken ſeparately; nor even collectively, without the co-operation of other principles, as experiments have proved.

Theſe other principles are *water*, which forms the greateſt part of the ſubſtance of vegetables, and an original ſubſtance called *coal*, or *charcoal*, and ſometimes *the carbonic principle*. Theſe two, together with ſmall portions of the primitive earths, and ſtill ſmaller of various ſalts (which laſt ſeem to be rather the ſtimulants, than the materials of vegetation), are found by chemical analyſis to be ultimately the conſtituent parts of vegetables; from whence it ſeems rightly inferred, that they are in their reſpective proportions the food of plants.

It hence appears, that the different earths are neceſſary to vegetation in the firſt place, as conſtituting an indiſpenſable though ſmall part of the food of plants. But their more important uſe conſiſts in being receptacles for containing, and inſtruments for conveying the other and more copious materials of vegetation. Of theſe other materials, *coal* and *ſalts* are contained in all mixed earths of which ſoils generally conſiſt; and *water* is retained abundantly by clays and argillaceous loams; moderately by calcareous loams; and very ſcantily by ſiliceous or ſandy ſoils. But it is not ſufficient for fertility that theſe principles ſhould be ſimply conveyed to the abſorbent veſſels of plants; they ſhould be conveyed in their juſt proportion, particularly *water*, an exceſs or defect of which is of principal injury to vegetation.

Hence it ſeems a prime object in agriculture, to give ſuch a texture to the ſoil as may enable it to retain a ſufficient quantity of water, and no more; and this is accompliſhed by a juſt combination of the primitive earths, viz. the *argillaceous*, the *ſiliceous*, and the *calcareous* (under which laſt magneſia is included).

The proportions of theſe earths requiſite to form a fertile ſoil, are not every where the ſame, but are found to vary with the climate; and it is naturally to be expected, that the more moiſt the climate, the leſs ought to be the retentive power of the compound ſoil, and, of conſequence, that the ſiliceous and calcareous ingredients ſhould predominate more there, than in drier climates, and vice verſa. And this concluſion is amply verified by the analyſis of fertile ſoils in different climates; the proportion of the ingredients being found to bear this reference to the average quantity of rain, as far as experiments have been made. For the adjuſtment of this proportion, in bringing a ſoil to proper texture, it may be uſeful to know more preciſely the ratio of the retentive powers of argillaceous, calcareous, and ſiliceous earths, which are reſpectively as 10, 2, and 1; the firſt being juſt ſaturated with $2\frac{1}{2}$ times its own weight of water, the ſecond with $\frac{1}{2}$, and the third with $\frac{1}{4}$, as we learn from the experiments of Mr. Bergman.

Though a proper texture is neceſſary for the purpoſe of fertilizing a ſoil, yet it is not of itſelf, nor even with the addition of water, adequate to complete that effect; as is evinced by the experiment of Mr. Giobert, in which he mixed the pure earths in ſeveral compounds of various proportions, and though he added water to each, yet no grain would grow in them; but when in the place of water he uſed the drainings of a dunghill, the grain grew proſperouſly, the cauſe of which plainly was, becauſe in conjunction with the other requiſites, the carbonaceous principle was now added to the compound, it being abundantly contained in the drainings of the dunghill, as is evident from this, that on evaporating that liquid ſubſtance, the principal part of the reſidue is found to conſiſt of coal. This experiment then clearly proves the neceſſity of this principle to vegetation; and hence appears the cauſe why dung is an uſeful manure to all kinds of land, as containing coal, which is ſo important a requiſite for the growth of plants. Mixed ſoils themſelves contain coal: it is likewiſe afforded by fixed air, more generally perhaps than by any other conveyance, for this air is often combined with the earth itſelf; it is diſengaged into the atmoſphere by various proceſſes of nature and art, and ſoon precipitating by means of its ſuperior weight, is abſorbed by the ſoil. All fermentations and putrefactions within the ground diſcharge it, and the freſh-turned earth attracts it in abundance from the atmoſphere.

By all theſe means a large ſupply of the carbonaceous principle is provided for fertilizing a ſoil of proper texture; for that ſubſtance, when incorporated with water, conſtitutes, as has been ſaid, a principal food of plants. But, by conſtant cropping, both the earth and coal that enter into the compoſition of vegetables are carried off, and the ſoil thus left deſtitute of a ſufficient quantity of theſe materials, not only becomes deficient in its ſtore of food for vegetables, but, by the change made in the proportion of its earths, its texture and retentive power become diſadvantageouſly altered. Then it becomes neceſſary for the ſupply of the carbonaceous principle to add dung, which contains it plentifully; to fallow the land, by which that ſubſtance is attracted in fixed air from the atmoſphere, and produced from the putrefaction of vegetable rubbiſh, buried by this operation in the earth; to apply calcareous earth in the form of lime, marle, or gypſum (according to the difference of ſoils), by the ſeptic or putrifying quality of which a ſimilar putrefaction produces a like ſupply of coal, while, at the ſame time, an earth is added, which is uſeful as well for improving the texture of the ſoil, as for ſupplying one principle of the food of plants. The fermentation excited by different manures, eſpecially calcareous ones, has alſo a great tendency to looſen and mellow the ſoil, when they are judiciouſly applied.

The texture of a ſoil neceſſary to fertility in any particular climate, and the proportion of the earths neceſſary to conſtitute it, are to be determined by the examination and analyſis of ſuch natural ſoils, as are found by experience to be moſt fertile in that climate. To theſe, as to a model, the artificial ſoils are to be conformed, which are the reſult of compounding manures with defective land. And this imitation will be rendered more perfect, in proportion to the ſkill and capital employed in the undertaking, and the effect probably will be proportionably advantageous. But though great preciſion may be attainable by ſome perſons peculiarly qualified, and under favourable circumſtances, yet it cannot be hoped for in general practice. Yet this may be materially improved by the accommodation of juſt principles to particular caſes, even where ſcientific exactneſs is not attempted. Thus, where clay predominates in the ſoil, limeſtone-gravel, or marles abounding in calcareous and ſiliceous earths, or artificial marles compounded of gravelly tills and lime, or ſea-ſand in which calcareous ſhells are mixed, are the appropriate manures, as ſupplying the deficient materials of vegetation, promoting the fermentation and putreſcence of roots and weeds, and altering the compoſition of the ſoil into a due texture. The two former effects are ſtill further produced, by combining dung with the ſubſtances applied.

In ſoils where ſand and gravel take the lead, marles rich in calcareous and argillaceous earths, or artificial marles formed by the mixture of lime with clay and heavy loams, appear, for ſimilar reaſons, the moſt advantageous manures, and are found to be ſo.

Light limeſtone and chalky lands require clay or argillaceous loam, which ſupply the earths deficient in ſuch ſoils.

Lime *alone*, is moſt advantageouſly applied to tilly and vitriolic, and peat or boggy ſoils, as it corrects the vicious acidities with which they are impregnated. And though on other lands lime is moſt beneficial when applied in ſuch mixtures as thoſe above-mentioned, yet, when uſed alone, it is likewiſe highly ſerviceable to every ſpecies of ſoil, wet clays and bare ſands excepted. In the former it is clotted by the ſuperabundant moiſture, and rendered incapable of a general diffuſion through the ſoil, on which its effect much depends.

This exceſs of water likewiſe greatly diminiſhes its ſeptic power, one of its principal means of improvement: On the contrary, when it is mixed with bare ſand, the compound has not a ſufficiently retentive power; it is apt to cake hard, like mortar, and the argillaceous ingredient is wanting. Where the marles beſt adapted to aſſiſt defective ſoils, or the compounds made in imitation of them, cannot be procured, *ſome* amendment may be made by the application of ſimple earths. For example: Sand, or very ſandy loams, will be improved by the addition of clay in ſome degree, though not ſo much as by argillaceous marle. Clays, or argillaceous loams, are aſſiſted by incorporating with them rough ſand, though not ſo much as by the application of limeſtone-gravel. For in theſe and the like caſes the texture is ameliorated, and though not all, yet many of the deficiencies of the ſoil are ſupplied.

SECT. II.

OF SALINE SUBSTANCES.

CHAP. I.

Of the different kinds of SALTS.

SALINE ſubſtances are ſuch as poſſeſs taſte and are ſoluble in water. This is the moſt general deſcription given of them : but ſome Chemiſts add other properties ſuch as a remarkable tendency to combine with other ſubſtances and a want of combuſtibility. None of theſe properties however prevail equally in all ſalts ; ſome for inſtance have ſo ſtrong a taſte, as to corrode and deſtroy our organs whence they are called cauſtic. Others, without having ſo great ſtrength have yet a very ſenſible taſte called by the names of bitterneſs, aſtringency, &c. : And laſtly ſome ſalts appear inſipid, and either to want taſte altogether or to poſſeſs in it a very ſlight degree. The ſame thing may be ſaid of their ſolubility in water, which in ſome ſalts is ſo great that they inſtantly diſſolve, and ſome cannot be freed from the laſt portions of water but by the moſt tedious proceſſes. Others are ſoluble in a moderate degree, and others ſcarce at all. And ſo of the remaining properties.

Some learned men imagine, that the cauſticity of certain ſaline ſubſtances is nothing more than their ſtrong tendency to combine with our organs. And they maintain their opinion by theſe facts: 1ſt. Thoſe ſubſtances which have the ſtrongeſt taſte have the greateſt tendency to combination: 2d. Thoſe which have not this laſt quality have but a weak taſte: 3d. A cauſtic body whoſe tendency to combination is ſatisfied, at the ſame time loſes its taſte: 4. A cauſtic body which exerts all its force upon our organs deſtroys them, and accordingly loſes its cauſticity.

Salts are divided into three kinds, Acid, Alkali, and Neutral.

Acids, beſides their ſharp taſte, poſſeſs with few exceptions the property of changing the blue colour of vegetables ſuch as ſyrup of violets into a red, and this is reckoned a diſtinguiſhing character of acids.

We have already obſerved the diviſion of earthly ſubſtances into three kingdoms, the mineral, vegetable and animal. Agreeably to this diviſion, acids are diſtinguiſhed according to the nature of the ſubject from which they are produced.

Among the mineral acids the moſt remarkable are the Vitriolic, the Nitrous and the Marine, which are ſeparated in large quantities by diſtillation from vitriol, nitre, and ſea-ſalt; vitriolic is alſo had from burning ſulphur. Vegetable acids are either native ſuch as exiſt in ſour fruits and plants; or factitious, ſuch as vinegar and tartar, which are produced by fermentation.

Animal acids are ſuch, as may be ſeparated from various parts of animals by diſtillation: or they are ſuch as bees, ants, and other inſects contain in proper veſſels ready prepared, and which they throw out in ſtinging.

Alkalies are ſalts, which are generally obtained from the aſhes of marine plants, or other vegetables, or from the aſhes of certain animal ſubſtances ſuch as bones, dung &c. The firſt of theſe is called mineral alkali, the ſecond, vegetable alkali and the third volatile alkali.

Of theſe alkalies the two former are called fixed, for they are not diſſipated by any heat ſhort of a naked fire heat. The third being much more eaſily diſſipated is called volatile.

Alkalies change the blue colour of vegetables ſuch as ſyrup of violets into a green, and this is reckoned a diſtinguiſhing character of theſe ſalts.

Neutral ſalts are a combination of acids and alkalies; we will treat of Alkalies firſt.

CHAP. II.

Of Alkalies: viz. the Mineral, Vegetable, and Volatile Alkalies.

THE name *Alkali* is derived from the word Kali, a maritime plant which is called by us Glaſſwort or Marſh Samphire. This plant being burned, its aſhes are boiled and waſhed into a Ley; which is filtered and evaporated and thus the ſalt called Alkali is obtained. This ſalt has been alſo called *ſalt of ſoda*, becauſe it is moſt frequently extracted from a plant of that name. It is likewiſe obtained from other maritime plants, as Barilla, Algazul, Salicornia and alſo from ſea-wrack in the following manner. The plants are cut from the rocks or gathered on the beach, and being ſufficiently dried by the ſummer's ſun, they are ſet on fire in a hole made in the ground: the melted maſs is kept in a ſtate of fuſion for ſome hours, and then ſuffered to cool: It is called Kelp, and is employed in the manufacture of ſoap and glaſs. The Alkaline ſalt contained in the aſhes of maritime plants when expoſed to the heat of a glaſs-houſe furnace loſes much of its weight, but in moderate fires loſes nothing; hence this ſalt, as we obſerved, is called a fixed Alkali: and being found to compoſe half the weight of common ſalt, which is reckoned a mineral from being often found in large mines, this alkali has been called *mineral*, *foſſile*, or *marine* fixed alkali.

The ſaline matter found upon old damp walls is this mineral alkali combined with fixed air and water. The aſhes of moſt other vegetables as well as of maritime plants yield a ſalt which has many and the moſt important properties in common with the mineral alkali, but not poſſeſſing all the ſame properties, has for diſtinction's ſake been called the *vegetable fixed alkali*: this is obtained by the ſame proceſs as the mineral alkali, and is uſed to the ſame valuable purpoſes. It is ſometimes called *potaſh* from the evaporation by which it is obtained being made in large iron or copper pots. The pureſt kind is that which is made from tartar, a vegetable production which forms upon the ſides of caſks containing new wine: This is wrapped in wet paper, and burned in a furnace with charcoal moderately heated; and the pure ſalt, obtained by waſhing the aſhes and evaporation is called *ſalt of tartar*. Fixed Alkali when pure is dry and white; to obtain it in this ſtate the evaporation of the Ley ought to be made in cloſe veſſels, or the ſalt to be calcined and dried with a gentle heat. Vegetable Alkali if expoſed to the air in a moiſt place, will almoſt all be melted into a thick tranſparent liquid, which weighs four times as much as the ſalt when dry; Mineral alkali if expoſed in the ſame way will not be changed into ſuch a fluid; whence it appears that its attraction to water is not ſo ſtrong as that of vegetable alkali; neither does it attract the acids with ſo much force, as is demonſtrated from the vegetable alkali decompoſing neutral ſalts of which the mineral alkali makes a part. It may be owing to this that theſe two alkalies form very different compounds when in combination with thoſe ſubſtances. Such are the moſt remarkable differences obſerved between the fixed alkalies. They agree in the following reſpects. They are both cauſtic, they change the blue colour of vegetables to a green; they have both a tendency to combine with ſeveral other ſubſtances, as water, inflammable ſubſtances, and above all acids; they melt in a moderate heat and in a ſtronger become volatile; they diſſolve earth and the calces of metals in the dry way.

Alkalies, which contain fixed air, are called mild alkalies; when deprived of their fixed air by boiling them in water with lime (for the lime attracts the fixed air and becomes chalk) they are then cauſtic.

A ſolution of this kind combined with about ſix times its weight of oil forms ſoap. The ſolution is drawn off three times; called the firſt, ſecond, and third Ley. With this laſt Ley the oil is firſt put into the boiler, and the mixture kept conſtantly agitated. When this Ley has been all put in by degrees, the ſecond is added in the ſame manner; and then the firſt. The ſoap now begins to form, and ſome common ſalt is thrown in which compleats the formation, by ſeparating the water from the ſoap, to which the water has leſs affinity than to the ſalt. The ſoap is well made, if it appears firm and white, and if it completely mixes with water, ſo as that no greaſe ſhould be ſeen on the ſurface. Frauds are ſometimes committed in this manufacture, by mixing ingredients which encreaſe the weight without adding to the value: for this purpoſe water is chiefly uſed, eſpecially in ſoap made with tallow: but as it evaporates in open air and ſo loſes weight, the ſoap is uſually kept in ſtrong ſolutions of common ſalt, by which means the weight of it is rather encreaſed. Two pieces of ſoap made in this fraudulent manner were put, one in a dry place expoſed to air, the other in a ſolution of ſalt: At the end of a month the former had loſt half its weight, the latter had gained one tenth. Mineral Alkali makes *hard ſoap*, vegetable alkali a *ſoft ſoap* of the conſiſtence of honey.

Fixed Alkali is equally uſeful in the compoſition of *glaſs*: which is made by mixing in proper proportions with alkali the different ſpecies of ſiliceous earth according to the quality of the glaſs, from the fineſt to the coarſeſt flinty ſand: theſe are heated together till they are fuſed in a furnace. The melted matter is taken out at the end of a long hollow tube which is dipped ſeveral times into it and turned about, until a ſufficient quantity is taken up; the workman at each turn rolling it gently upon a piece of plate-iron, to bind the melted maſs more firmly. He then blows through the tube, till the metal ſwells at the end like a bladder, after which he rolls it on a marble ſtone to poliſh it, and repeats the blowing, until the glaſs is brought as near the ſize and form of the veſſel required as he thinks neceſſary. If it be a common bottle, the melted matter at the end of the tube is put into a hollow ſhape equal to its body, and the neck is formed on the outſide by drawing out the ductile glaſs. If it be a veſſel with a large mouth, the glaſs in its ſoft ſtate is opened, and widened with an iron inſtrument for this purpoſe; after which being again heated, it is whirled about with a circular motion, and by means of a centrifugal force thus produced is extended to the ſize required. Should a handle, foot, or any thing elſe of the kind be required, theſe are made ſeparately and ſtuck on in a melting ſtate. A ſimilar proceſs is uſed for making window glaſs except that the maſs at the end of the tube is formed into a cylindrical ſhape, which being cut in length by ſcizzars or ſhears is gradually bent back until it becomes a flat plate.

Large plate glaſs for mirrors is made by running glaſs compoſed of the fineſt materials in a ſtate of perfect fuſion upon a caſting table, with iron ledges to confine the melted matter, and, as it cools, rolling over it a braſs roller to reduce it to an uniform thickneſs. The plate of glaſs is at firſt near an inch thick: its aſperities are afterwards ground away with ſand and emery, after which it is poliſhed. Plates of ten feet in length, and ſix in breadth have been made in this manner.

When glaſs is completely formed, it muſt be *annealed*; that is, placed in an oven heated to a certain degree, in order to cool ſlowly; becauſe a ſudden tranſition from heat to cold is very apt to crack the glaſs, probably by the force of the heat endeavouring to reſtore an equilibrium, and meeting with reſiſtance from the parts of the glaſs becoming ſolid.

The points to be moſt attended to in making the finer kinds of glaſs are, the purity of the materials, the proportion of them to each other, and the management of the fire. Pearl aſhes well purified, with twice or three times its weight of fine clean flint ſand, adding ſome common ſalt, a little nitre, arſenic and borax to aſſiſt the fuſion as fluxes, are found for the conſtruction of large mirror glaſs to ſucceed well. Too great a quantity of alkali will give the glaſs a diſpoſition to alter by the action of acids. In conducting the heat, the greateſt regularity ſhould be obſerved;

for by being ſuddenly raiſed, air bubbles are apt to eſcape; and if during this the melted glaſs ſhould happen to be taken up, it will abound with cavities which injure its tranſparency, and ſometimes expoſe it to be broken. Specks or colours in the glaſs are owing to foreign matters, which cannot be vitrified. And there is one defect, for which no compleat remedy has yet been found, ariſing from the lower parts of the fuſed glaſs being denſer than the higher, which produces a ſort of greeniſh lump that defaces the uniform beauty of the glaſs. To prevent the ſwelling of the materials upon their firſt combination, they ought to be expoſed to a gentle heat: by which means moſt of the volatile matters are driven off, and the ingredients more intimately blended.

The Calces of different metals being fuſed along with glaſs, produce that beautiful compoſition called *Enamel*; which is variouſly coloured according to the metal employed. Roſe, red, and purple colours are prepared from gold, green from copper, blue from cobalt, white from tin &c. &c. And even the ſame metallic calx will give different colours according to different degrees of heat: thus the green of common glaſs bottles is changed to blue.

The fineſt of theſe colours are employed in painting porcelain, glaſs, or other enamels. The colours are laid on with a pencil; and, being burned in, laſt as long as the ſubſtances on which they are laid. It is called enamel painting. Sometimes the compoſition of glaſs with the metallic calces is made to emulate the precious ſtones of different colours, Amethyſts, Rubies, Topaz &c. And ſometimes it is employed to enamel metals, eſpceially gold, by ſpreading the compoſition in a liquid ſtate upon its ſurface, to which it adheres for a long time.

The ductility of glaſs is very curious and ſurpriſing. If a thread of melting glaſs be drawn out, and faſtened to a reel; the whole of the glaſs can be ſpun off on the reel, and by cutting the threads there is obtained a ſort of ſilver feather, which is ſometimes uſed as an ornament to the head.

Before we leave this ſubject, it is worth obſerving, that glaſs is corroded by an acid contained in Derbyſhire ſpar: which acid is therefore employed in making etchings or engravings on glaſs.

The third kind of alkali is called the *Volatile Alkali*, which is ſometimes called ſpirit of hartshorn; it is a ſalt for the moſt part obtained from animal ſubſtances, as urine, bones, dung &c. This alkali is diſtinguiſhed from the two former not only in its great volatility, but alſo in its pungent and ſuffocating odour. Pure volatile alkali is not the ſubſtance which generally goes under this name, but an elaſtic air or alkaline gas, that is driven off by a gentle heat from what is called the volatile cauſtic alkali, which holds it in ſolution. This gas extinguiſhes burning bodies, and kills animals. Common volatile alkali is ſometimes extracted from Sal Ammoniac, a ſalt formerly imported from Egypt, where it is procured from the ſoot of Camels dung, the component parts of it being the volatile alkali and the marine acid: but both the alkali and ammoniac are now for the moſt part prepared at home, the former from burning bones, ſoot &c. which being obtained, the latter is compoſed by adding to the alkali ſome vitriolic acid and common ſalt: In this caſe a double elective attraction as we had occaſion to obſerve before, takes place. The vitriolic acid uniting with the mineral alkali forms Glauber's ſalt, and the marine acid uniting with the volatile alkali forms ſal-ammoniac. Evaporation ſeparates the ſalts in chryſtals, and the ſal-ammoniac is ſublimed and made into cakes for ſale.

As the ſal-ammoniac was obtained by ſyntheſis, ſo may the volatile alkali be had by analyſis; if to ſal-ammoniac twice the quantity of powdered chalk be added, and the mixture be expoſed to a ſand-heat in a retort with a receiver adapted. While the marine acid and lime remain in the retort forming an earthy ſalt, the volatile alkali and fixed air are driven over into the receiver where they compoſe the ſalt called *Sal Volatile*: a ſalt of conſiderable uſe in medicine, particularly in reviving faint and languid ſpirits.

All the alkalies unite with fixed air: If a ſmall quantity of ſolution of cauſtic alkali be poured on the inward ſides of a veſſel containing fixed air, and the veſſel be covered with a moiſt bladder, the bladder falls down by degrees becauſe the fixed air being imbibed by the cauſtic alkali, a vacuum or void ſpace is left within. Chryſtals are formed and depoſited on the ſides by this combination.

Beſide the uſes of Alkalies already mentioned, they are of important ſervice in the arts of dyeing, colour-making, bleaching, and others.

In bleaching they are employed to make Lixives or Lyes for that part of the proceſs called bucking, and boiling, the deſign of which is to looſen, and carry off that particular ſubſtance in cloth, which is the cauſe of its brown colour. Their application in dyeing, and extracting the colouring matter of certain ſubſtances will be ſhewn hereafter.

CHAP. III.

Of Vitriolic or Sulphuric Acid, and Sulphur.

VITRIOLIC ACID is, as the name imports, the acid, which makes part of a ſalt called *vitriol.* This ſalt is procured from *pyrites*, a mineral ſubſtance, compoſed chiefly of iron and ſulphur; and which, by expoſure to air and moiſture, undergoes a ſpontaneous change, acquiring a conſiderable degree of heat, breaking and falling to pieces. The reſidue, which is found after this natural proceſs, is diſſolved in boiling water, and then evaporated; by which means the cryſtals of the ſalt are ſeparated from the earthy impurities; and being found to be of a greeniſh glaſſy appearance, they are hence called *green vitriol.* If this ſalt be diſtilled in a retort, the vitriolic acid comes over into the receiver, leaving behind a reſidue called *colcothar of vitriol*, a red powder uſed in painting, and alſo for poliſhing mirrors.

This method of obtaining the acid was extremely difficult; it is therefore now produced by the combuſtion of ſulphur, and hence called *ſulphuric acid.* Sulphur or brimſtone is a hard, brittle, inflammable ſubſtance, of a yellow colour;

it is found in great quantities in nature, ſometimes pure, and ſometimes combined; for the moſt part in the neighbourhood of volcanoes, where it ſeems to be driven out by ſubterraneous fires. This is rendered highly probable by a ſimple experiment, which ſatisfactorily proves the origin of thoſe fires.

Let equal quantities of powdered ſulphur and iron filings be mixed together, and kneaded with a little water into the conſiſtence of a paſte. Let this be put into an iron pot, covered with a cloth, and buried about a foot under ground: after ſome time the earth begins to ſwell, grows warm, and cracks; hot ſulphureous vapours are exhaled, a flame between the cracks is obſerved, and the earth is covered with a yellow and black powder; in ſhort, there are all the appearances of a volcano.

To reaſon then from this experiment to the proceſs of nature: there is no mineral more commonly found than that which is compoſed of iron and ſulphur, under the various names of copperas-ſtone, pundic, brazil, braſs-lumps, and pyrites: (This laſt name has been given to it from its ſtriking fire with ſteel, and from its taking fire when laid in heaps, and moiſtened with water). It is alſo well known that water abounds below the ſurface of the earth, and that air can be admitted, either by accompanying the water, or by making its way through the fiſſures and openings on the ſurface; and thus, the materials required in the experiment being provided by nature, the ſame effects will follow. From theſe pyrites ſulphur is extracted, by placing them in earthen veſſels, ſo diſpoſed in a furnace, that, when the ſulphureous part melts, it runs into other veſſels filled with water, and there congeals. Sulphur in ſticks has been run into cylindrical moulds of wood. When procured in this manner it is impure, and, in order to obtain it in a pure ſtate, the ſulphur muſt be heated in a cloſe veſſel with a gentle heat, a little above what is ſufficient to melt it: the fine powder which is ſublimed is called *flowers of ſulphur.*

If ſulphur be heated in the open air, it firſt melts, and ſoon after taking fire, it burns with a blueiſh flame, at the ſame time exhaling a moſt ſuffocating vapour, which kills animals, and extinguiſhes flame. This vapour unites with water, producing a briſk heat and hiſſing noiſe, and diſcharging a nauſeous ſmell. The combination in this ſtate is called *volatile vitriolic acid;* but remaining ſome time expoſed to the air, the acid becomes fixed, and loſes its ſmell, when it is called *the ſpirit of vitriol*; and, if part of the water be evaporated, the acid is more concentrated, and is now called *oil of vitriol;* probably from the little noiſe it makes when poured out, and from its unctuous or greaſy feel between the fingers, the ſkin of which it corrodes, forming with it a kind of ſoapy compound. If the ſulphur were perfectly pure in this experiment, and the heat continued, the whole ſulphur would burn away without leaving any reſidue.

Sulphuric acid is ſo uſeful in the arts and manufactures, that the making of it is very important. It is obtained from ſulphur, by burning a mixture of eight parts of this with one of nitre, in veſſels well cloſed, and containing water. The nitre is neceſſary, becauſe it ſupplies vital air in abundance, without which the cumbuſtion could not proceed. The veſſels muſt be well cloſed, to prevent the eſcape of the ſulphureous vapour which is the acid, and water muſt be preſent to imbibe it. The general method of obtaining this acid in the large way is, by burning ſulphur and nitre upon gridirons, placed in large chambers, lined with lead, and containing water; from which chambers the condenſed acid may flow through pipes into a reſervoir.

Pure concentrated ſulphuric acid is colourleſs, and emits no fumes. It attracts more than twice its weight of water from the atmoſphere, if ſuffered to remain in open veſſels: it cannot be entirely ſeparated from the water, to which it is united, by any known means. When it is diſtilled, the watery part firſt riſes, leaving the acid more concentrated: as the proceſs goes on, the acid riſes with the water. It has no action on the quartzy or ſiliceous earths, but in part diſſolves thoſe which have been fuſed with alkalies. It combines with clay, terra ponderoſa, magneſia, quick-lime, metals, and moſt combuſtible ſubſtances,

ſtances, and with all the alkalies; but ſaturates near twice as much fixed as volatile alkali.

With argillaceous earth or clay, ſulphuric acid forms *alum*, which, however, is not made for commercial purpoſes in this way, but is extracted from ores. In the neighbourhood of volcanoes, where it is often found ready formed, it is extracted by boiling and waſhing, and by ſubſequent evaporation. It is alſo made from a black ſlaty ſubſtance called *ſhale*, which contains a good deal of bitumen. During its calcination, the ſhale emits a ſulphureous acid, contained in the bitumen, which uniting to its ſlaty earth, forms alum. About 120 tons of calcined ſhale make one ton of alum. The ſhale, when calcined, is ſteeped in water, by which means the alum is diſſolved; and this afterwards undergoes other operations. The making of it coſts about ten pounds a ton. Beſide many other uſes, to which alum is applied, it is of the moſt important ſervice in the art of Dyeing.

With lime, the ſulphuric acid makes ſelenite, gypſum, or plaiſter of Paris. This ſaline ſubſtance is found abundantly in nature: the lapis ſpecularis and alabaſter are of this kind. Gypſum is employed in making cielings, cornices, and medallions; and likewiſe, for taking off impreſſions in a mould, by making it with water into a ſort of paſte.

With magneſia, it forms Epſom ſalt. In the ſtate of this ſalt magneſia is generally found in nature; and it is obtained by diſſolving the ſalt in water, and adding half its weight of potaſh: the magneſia is precipitated, and, being waſhed and dried, appears in the form of a ſoft white powder.

With barytes, the ſulphuric acid forms ponderous ſpar, or marmor metallicum, of uſe in ſtrong fluxes. Barytes, as well as magneſia, is generally found in nature, combined with this acid. To procure it, the ſpar is to be pounded, mixed with twice or thrice its weight of potaſh, and expoſed to a red heat. The acid and alkali unite, and leave the barytes.

With the vegetable alkali, it forms vitriolated tartar; and with mineral alkali, Glauber's ſalt; both uſed as purgatives in medicine: and with volatile alkali, vitriolic ammoniac, which diſſolves moſt metals, except gold.

Sulphuric acid is one of thoſe acids which adheres moſt ſtrongly to its baſes: the combinations with which, eſpecially the moſt important, ſhall be conſidered, when thoſe baſes are particularly examined. If combuſtible bodies be combined with this acid, they decompoſe it, and diſengage, for the moſt part, a ſulphureous gas, of the ſame nature with the vapour of burning ſulphur; and ſometimes, alſo, an inflammable gas, as when metals combine with the acid in a diluted ſtate. Whereas the nitrous acid, in combinations with combuſtible bodies, always diſengages a nitrous gas. The ſulphureous gas, as we have ſeen, is imbibed by water: if this be faſt cloſed for ſome days, ſulphur is depoſited. Whence ſulphur and the nitrous gas ſeem to bear the ſame relation to their reſpective acids; and, as will hereafter appear, each of them, in combination with vital air, produces its own acid. As ſulphur has been ſhewn to yield ſulphuric acid, ſo may this acid be converted into ſulphur; by fuſing equal parts of vitriolated tartar and vegetable alkali together in a crucible, and by adding half a part of powdered charcoal. The whole being well ſtirred, and heated ſtrongly, is poured out ſparkling upon a ſmooth ſtone, previouſly well greaſed. When the maſs is cool, it is diſſolved in water, and an acid added to the ſolution, which ſtrongly unites to the alkali: ſulphur is precipitated. The additional alkali uſed in the experiment, probably ſerves to aſſiſt the fuſion of the original maſs; and alſo, by combining with the acid, to prevent it from flying off, till in the proceſs it acquires a ſolid form, either by receiving phlogiſton from the charcoal, or loſing vital air; by either of which means the ſulphuric acid was during combuſtion changed into ſulphur.

An alkaline liver of ſulphur is a combination of the flowers of ſulphur with fixed alkali. Theſe livers of ſulphur, called ſometimes *hepars*, are of different kinds, according to the ſubſtance with which the flowers of ſulphur are combined. If they are combined with lime, they are called calcareous livers of ſulphur, and ſo of others. If water be poured upon a mixture of hot quick-lime and flowers of ſulphur, the heat occaſioned by the action of the lime is ſufficient to promote their union; and if more water be added, the mixture aſſumes a reddiſh colour, and emits a fetid odour. It is readily altered by the air, and loſes its colour and odour according as the hepatic gas eſcapes. It is decompoſed by the alkalies, which from their ſtronger attraction to ſulphur precipitate the lime; and by acids, which, from their ſtronger attraction to lime, precipitate the ſulphur in a fine powder called *magiſtery of ſulphur*.

The alkaline livers of ſulphur differ conſiderably, according as the alkalies are *cauſtic* or *mild;* the former being deeper coloured, ſtronger, and more alterable, and the gas more fetid and inflammable than the latter. They are made in the moiſt way, but aſſiſted by heat, if half the weight of ſulphur be boiled in a ſolution of fixed alkali; or in the dry way, if equal weights be melted in a crucible, and poured out on a ſmooth ſtone.

Acids, by decompoſing all the livers of ſulphur, diſengage an hepatic or fetid gas, whoſe ſmell is inſupportable. It kills animals ſuddenly, turns the ſyrup of violets green, and ſome metallic calces quite black. It burns with a ſlight blueiſh flame, and, when kindled in glaſs veſſels, depoſits on their ſides flakes of ſulphur. It is decompoſed by the air, and depoſits ſulphur in this caſe alſo.

The volatile cauſtic alkali has but very little effect upon ſulphur in the ſolid form, but affords a liver of ſulphur, if they are preſented to each other in the form of vapour. Let equal parts of quick-lime and ſal-ammoniac, with half a part of ſulphur, be diſtilled, and let the volatile parts, viz. the volatile alkali and the ſulphureous gas, when driven over, be combined with a little water, contained in the receiver; theſe will give a volatile liver of ſulphur, called the *fuming liquor of Boyle*. A few drops of oil of vitriol let fall on this, produce a great degree of heat and agitation, followed by a violent exploſion. This was accidentally diſcovered by Mr. Fourcroy, miſtaking *oil of vitriol* for *ſpirit of vitriol*.

Sulphur is of excellent uſe in diſeaſes of the lungs and ſkin; and the livers of ſulphur are thought good for obſtructions, numbneſſes, palſies, &c. It is alſo of great uſe in the arts, being one of the component parts of gunpowder, making combuſtible matches, &c. It is uſed to whiten ſilks, and to deſtroy certain colours, by means of its acid vapour, and to ſtop the fermentation of wines, &c. The acid of ſulphur is much employed in the manufacture of linen, to whiten the cloth.

CHAP. IV.

Of Nitrous Acid and Nitre.

NITROUS ACID is the acid of a neutral ſalt called Nitre, or Saltpêtre; and conſiſts of two airs, pure air, and the nitrous gas. In the fluid form in which it appears, it is combined with water, and is of a yellow or red colour: it turns the blue of ſyrup of violets into red, and is ſo cauſtic as to corrode the fleſh of animals.—It is extremely volatile, ſo as to be evaporated in the common heat of the atmoſphere: it unites rapidly with water and gives out heat, and when diluted a good deal loſes its colour, in which ſtate it is called *aqua-fortis*.

Nitrous acid unites with lime, magneſia, terra ponderoſa, clay, and the alkalies forming with theſe ſeverally as baſes various ſalts. When combined with combuſtible ſubſtances it calcines them, and diſengages an air called *nitrous gas*, which is unfit for reſpiration or combuſtion, and which ſuddenly unites with vital air, forming with it *nitrous acid*.—As ſoon as the two airs come in contact, though both colourleſs, they become red, and when imbibed by water produce aqua-fortis—

ſo that the red cloud formed by them, was the nitrous acid in the aerial form. Dr. Prieſtly, from this property, made a number of moſt ingenious experiments to determine the purity of common air. He found that the more pure this was, the more apt was a mixture of the nitrous gas with it to produce thoſe red fumes and to be diminiſhed in bulk.—And hence he diſcovered what common air was more and what leſs reſpirable than others. So far then, as this particular cauſe is connected with health, his diſcovery is valuable; but not extending beyond the effects of air on reſpiration, and taking in none of thoſe actions which it has upon the ſtomach, the ſkin, and particularly the nerves, in theſe reſpects it muſt fail in always ſhewing the wholſomeſt air in which to live.—The air of two different places may have the ſame proportion of vital air, and, therefore, ſhew the ſame reſult in theſe experiments; and yet in the other component parts one of thoſe airs may be much more noxious than the other. Nitrous acid frequently exhibits different colours, as red, orange, green, and blue: this is probably owing to its attraction of nitrous air, for when expoſed to the action of this air, the acid changes to thoſe different colours, in the above order, according to the quantities of air imbibed. —The nitrous air which is thus imbibed afterwards eſcaping and uniting with the vital air of the atmoſphere, forms reddiſh fumes.

Water impregnated with nitrous acid, in the claſtic or aerial form, is changed ſucceſſively into blue, green, red, and yellow, continually increaſing in bulk, till at laſt it has gained one-third.

Nitrous acid mixed with all the oils obtained from vegetables, called eſſential oils, produces ſudden and great inflammation : if you mix fuming acid of nitre with oil of turpentine in the ſevereſt weather, when each of them is colder than ice, they will inſtantly take fire and burſt into a great flame. In making this dangerous experiment a long pole ought to be uſed, leſt the burning matter ſhould fall on the hands of the operator.

It does not appear in this and other caſes, that the ſimple mixture produces heat : the ſubſtances muſt act in ſome very different way, and this action does not take place immediately.—Sometimes the mixture will remain cold for ſeveral minutes, after which it heats and boils for a good while, as when fuming acid of nitre is mixed with two parts of ſpirit of wine : the very form of the bodies ſeems to be changed, and in the words of Dr. Hooke, (who firſt obſerved that vitriolic acid mixed with water took up leſs ſpace than might be expected from their ſeparate bulks) there is a penetration of their dimenſions.

Nitrous acid is obtained from nitre by diſtillation, moſt commonly as follows : let one part of pure ſulphuric acid be poured upon two parts by weight of nitre, and let the mixture be diſtilled—a very ſtrong acid comes over of a yellowiſh colour and ſuffocating ſmell, and having the property of emitting red fumes. By adding water to this acid its colour may be rendered firſt green, and then blue, but the fumes continue red.—This is called the acid of nitre, or ſpirit of nitre, and ſometimes Glauber's fuming ſpirit of nitre, from the name of the firſt diſcoverer. The acid was driven over, being diſengaged from the alkali of the nitre by the ſtronger elective attraction of this to the ſulphuric acid—and this is clearly proved from examining the reſidue in the retort, which is found to poſſeſs all the properties of a ſubſtance compoſed of ſulphuric acid and vegetable alkali.

A weaker ſpirit of nitre, called *aqua-fortis*, is ſometimes procured by diſtilling nitre in conjunction with green vitriol calcined to a certain degree, or with ſome ſort of clays, for many of theſe contain ſulphuric acid; but neither this nor the former are pure nitrous acid, becauſe part of the ſulphuric acid always comes over by diſtillation. However in the caſe of aqua-fortis this is ſometimes rather an advantage than the contrary, a ſlight mixture of the ſulphuric acid aſſiſting the nitrous acid in the arts of dyeing and engraving. It is otherwiſe in the refining of ſilver, where the nitrous acid ought to be pure, and therefore ſhould be obtained by diſtilling nitre with ſome ſubſtance not containing that acid.

Nitrous acid mixed with ſtrong ſulphuric is found to be a moſt powerful ſolvent of ſilver, though it has little effect on any other metal.

Nitre is formed by the union of the nitrous acid with the vegetable alkali; it has a cooling taſte, is perfectly neutral, and does not in the leaſt change the colour of ſyrup of violets.—This ſalt is found in places where the dung, urine, and other putrid matter of animals and vegetables are depoſited, as in ſtables, privies, &c. and alſo in vaults, or damp cellars, eſpecially if old lime, mortar, and other calcareous ſubſtances be near. If theſe circumſtances concur, and be aſſiſted by free contact of air, nitre will not fail to be produced.—It is with a view to theſe principles, that the proceſs of obtaining nitre by art is conducted.

Large pits are dug, or walls built, in dry places, over which ſheds are fixed, open at the ſides: this is done for the purpoſe of excluding rain, and admitting a free current of air. Theſe pits are then filled with rotten vegetables, dung of animals, and other putrid ſubſtances, together with looſe calcareous earth, rubbiſh, and ſuch matters; the maſs is watered and ſtirred from time to time, and after remaining ſome months in this ſituation, nitre is found to be formed. If the pits contained a great quantity of vegetable ſubſtances the ſalt will be common ſalt-petre; but if the lime and rubbiſh predominate, the ſalt will be what is called calcareous nitre.

The method of extracting the nitre is as follows: the maſs which contains it being pounded, is put into large caſks, with a cock at bottom, together with ſtraw to prevent the paſſage from being ſtopped, and alſo ſome aſhes—boiling water is then poured in, which diſſolves the ſalt and carries it off through the hole in the bottom; after it has ſtood for ſome time more water is poured in, for the purpoſe of extracting the whole of the ſalt, and the impregnated water is made to paſs again through other veſſels, with a view to ſaturate it, and ſo increaſe its ſtrength. It is then boiled and made to evaporate, the ſcum being taken off; and when the evaporation has been carried to a certain point, the common ſalt, which always makes part of the compoſition, falls to the bottom and may be taken out in ladles, the nitrous ſalt ſtill remaining ſuſpended: then the remaining fluid may be ſuffered to cool, and a great part of the nitre will form into cryſtals, while the common ſalt that is left continues diſſolved in the cold water. When theſe cryſtals are removed, ſubſequent evaporation will afford more; this is called nitre of the firſt boiling, and contains ſome common ſalt with calcareous and other matters; from which it is purified by diſſolving it in a ſmall quantity of water, and by clarifying this boiling liquor with ox-blood, which collects the impurities as they riſe from the bottom, and holds them on the ſurface. The cryſtals now obtained, after taking off the ſcum and evaporation, are a much purer ſalt than the former, and are called nitre of the ſecond boiling.—For nice purpoſes this proceſs is repeated four times.

It was obſerved, that at a certain point of the evaporation common ſalt fell to the bottom, while nitre was ſuſpended, and at another point this was reverſed: the reaſon of which is, that nitre is a great deal more ſoluble in hot than in cold water, whereas common ſalt is little more ſo—hence when ſo much water is evaporated, that enough does not remain to hold both ſalts in ſolution, the nitre will be held up by the heat of the water, which having little effect upon the common ſalt, this will precipitate.—And again, when the water becomes colder, the nitre will be no longer held in ſolution, as requiring ſix or eight times more cold water than hot; at the ſame time enough will remain to hold the common ſalt in ſolution, which requires little more of cold than of hot water for the purpoſe.

The mixture of nitre, ſulphur and charcoal in certain proportions is the compoſition called *gun-powder*, which proportions are in 100 pounds weight, about 75 pound of nitre 9 of ſulphur and 16 of charcoal. This mixture is pounded for ſeveral hours in a wooden mortar, with a peſtle of the ſame materials, and a very ſmall quantity of water is by degrees added. When it has been formed into a ſtiff paſte, from which moſt part of the water has been evaporated it is then reduced into grains by ſhaking it and paſſing it through ſeveral leather ſieves, which are moved backwards and forwards horizontally, the ſieves having holes of different ſizes by which the grains are formed. If theſe come not round from the ſieves, they are put into a barrel and rolled about, by which means they become round by rubbing againſt each other. The powder is alſo made ſmooth ſo as not to ſoil the fingers by moving the barrel quickly round an axis. But this ſmooth powder is not reckoned ſo good as the other, probably becauſe the grains are too cloſe and not ſo eaſily for that reaſon ſet on fire. Neither is any powder which is grained ſo ſtrong as when ſimply dried, becauſe more water is required for the former purpoſe, which cryſtallizes the nitre and thus ſeparates it from the other ſubſtances. And for the ſame reaſon, but in a much greater degree, it happens, that gunpowder, which has ever been wetted cannot by any drying be reſtored to its former ſtrength.

Gunpowder is ſometimes dried in apartments fronting the ſouth and admitting the ſun's heat. In warm countries this method ſeems preferable to any other, but in more temperate or cold climates it is neceſſary to reſort to artificial heat. They generally make uſe of ſtoves in England which are heated by large iron pots. Care ſhould be taken to regulate the heat ſo as that the ſulphur ſhould not evaporate, and on the other hand that the gunpowder ſhould be entirely freed from its moiſture. For from what has been ſaid it appears that moiſture even that of the atmoſphere greatly weakens its force, and on this account the ſaltpetre employed ought to be of the pureſt kind becauſe ſuch will not attract water from the atmoſphere whereas when mixed with common ſalt, it will do ſo very ſenſibly. The ſulphur alſo ſhould be choſen with care: that which is ſold under the name of flowers of ſulphur is preferable to that which is ſold in ſticks, although this be not very impure. But however pure the materials may be, this is of little uſe unleſs their mixture be intimate and perfect. When any grain of gunpowder takes fire, it inſtantly communicates the fire to the entire heap: this effect is called *Detonation*: which with the other known effects of gunpowder are owing to the expanſion of the elaſtic airs that are diſengaged. If the combuſtion ſhould be carried on by more ſlow and ſucceſſive degrees it is called *deflagration*. Nitre will not detonate unleſs ſome combuſtible matter be added to it.

Great and powerful as is the force of gunpowder, it is weak in compariſon of that of fulminating powder which is compoſed of 3 parts of nitre 2 of fixed ſalt of tartar, and 1 of ſulpher in powder. Theſe are bruiſed very fine and carefully mixed in a warm marble mortar with a wooden peſtle. If this mixture be fuſed in a ladle the effects are aſtoniſhing: an exploſion takes place (with only a drachm of it) louder than a cannon and the ladle is bent or diſfigured. Liver of ſulphur with nitre gives the ſame effect: whence it appears that the alkali of the tartar and the ſulphur of the former mixture form a true liver. It is probably owing to a much more inflammable hepatic gas being diſengaged in theſe laſt caſes, which combining with the vital air cauſes a more violent exploſion.

Nitre we have ſaid conſiſts of nitrous acid and vegetable alkali which may be proved by Syntheſis in the following manner. Pour ſome nitrous acid into a ſolution of potaſh, tartar or any other vegetable alkali, till no more effervefcence or boiling appears. Evaporate and cryſtallize the compound and it is found to be a perfect nitre: This uſually called *Regenerated Nitre.*

Nitre is of extenſive uſe in the arts as in making of glaſs and gunpowder and in ſmelting metals, by forming fuſing matters called fluxes. It is alſo conſidered a fine cooling medicine and an antiſeptic or means of prevention againſt putrefaction.

CHAP. V.

Of the Marine Acid and Sea-Salt, with obſervations on the Waters of the Sea.

THE *Marine Acid* is an acid which makes part of the compoſition of ſea-ſalt. In its uſual form it is a fluid like water, being when pure quite colourleſs. Like the other acids it reddens the ſyrup of violets and is cauſtic enough to corrode the ſkin and organs. If the veſſel in which it is contained be opened and the hand be applied to its neck a conſiderable heat is felt which is owing to a combination of the acid in its true ſtate of vapour with the external air. Dr. Prieſtly obtained it by diſtilling the ſtrong marine acid in a retort, whoſe neck was immerſed in quick-ſilver. The vapour which is more volatile than water came over and ſeemed like common air. It is however found to be much heavier, to inflame the ſkin and to ſuffocate animals. Pure air or atmoſpheric air coming into contact with it produces heat and cauſes white fumes: It combines rapidly with water and melts ice. In this union heat takes place.

The vapour here ſpoken of is called *marine acid air.*

Marine acid combined with vegetable alkali forms a ſalt called *Salt of Silvius*, which is ſometimes uſed in medicine; with the mineral alkali it forms common ſalt; and with the volatile alkali ſal ammoniac; on this laſt combination much heat is raiſed, a cloud is formed and the ſides of the veſſel hung with chryſtals of the ſalt. With lime it gives marine ſelenite, and with ponderous earth a ſalt of great uſe in detecting the preſence of ſulphuric acid which unites with the earth; and alſo for purifying the marine acid from any ſulphuric acid it might contain, in the ſame manner.

When diſtilled with calx of manganeſe the marine acid yields an elaſtic fluid which corrodes mercury, diſſolves gold, and is imbibed by water. It deſtroys blue vegetable colours making them white: it bleaches wax and has been uſed with ſucceſs in different manufactures. It is called *Dephlogiſticated Spirit of Salt or Marine Acid.*

Marine acid combined with nitrous acid forms *aqua-regia*, ſo called from being employed to diſſolve gold, the King of Metals. It is curious that two acids which ſeparately have no action on gold ſhould become capable of diſſolving it when united. For common purpoſes we may make aqua-regia by diſſolving *ſal ammoniac* in about four times its weight of ſtrong nitrous acid. The marine acid is diſengaged by the ſtronger attraction

tion of the volatile alkali to the nitrous acid; by which means a combination takes place between the acids that will anſwer well enough unleſs there be a great deal of alkali in the ſal ammoniac. Aqua Regia may alſo be obtained by diſtilling equal quantities of Sea Salt and Nitrous acid with a gentle heat after they have ſtood 10 or 12 hours. An acid comes over which is Aqua Regia.

Marine acid has a ſtrong attraction to ſilver and this property enables artiſts to purify nitrous acid, by adding to it a ſmall quantity of the nitrous ſolution of ſilver: the ſilver will unite with any marine acid which happens to be mixed in the nitrous acid, and fall down with it to the bottom leaving the nitrous acid more pure: care muſt be taken not to add too much of the ſolution.

Marine acid is obtained from common ſalt by diſtilling it in conjunction with ſulphuric acid in the ſame manner as nitrous acid is procured from nitre. The reſidue left after this diſtillation is found to be a ſubſtance agreeing in all its properties with that which is compounded of ſulphuric acid and mineral alkali, that is, Glauber's ſalt. And if the volatile product which came over be united with the mineral alkali a ſubſtance is compoſed reſembling in all its properties common ſalt. Whence it is evident that ſea-ſalt conſiſts of the marine acid united to the mineral alkali: the ſalt produced by this ſyntheſis is called *Regenerated Salt.*

Salt, whoſe compoſition has been juſt now mentioned, is found in great quantities in nature; as firſt in large maſſes or mines, in Calabria, Hungary, Muſcovy and particularly at Weilickſa in Poland, and Northwich in Cheſhire. When contained thus in the earth, it is generally of an irregular form, and ſeldom cryſtallized; it is ſometimes white, ſometimes coloured: in this ſtate it is called *ſal-gemmæ* becauſe it is generally tranſparent like the cryſtals called by that name. There are ſecondly many ſalt ſprings in various parts of the world; theſe are probably owing to the rain or other water ſinking through the earth, till it meets with the rock of ſalt, and being ſtopped there for ſome time, it becomes impregnated with the ſalt, after which it makes its way either above or below the rock, and comes out a ſalt ſpring. Laſtly the waters of the ſea every where abound with ſalt more or leſs. In this reſpect there are great differences. The waters of the Baltic are ſaid to contain not more than about $\frac{1}{64}$ part of their weight of ſalt; the German ocean about $\frac{1}{30}$ and between the tropics the ſea is ſaid by ſome to contain $\frac{1}{10}$, but others with more accuracy $\frac{1}{28}$.

From waters whether of the ſea or ſprings which contain ſalt, the general method of obtaining it is by evaporation. In very warm climates, the natural heat of the ſun is employed; and where this is ſufficient, it is the beſt method, and affords the pureſt ſalt; becauſe evaporation by fire cannot be ſo regularly conducted but tha many impurities will mix with the ſalt, and a portion of the acid be driven off, eſpecially if the boiling be at all violent. To obtain ſalt from ſea-water through the heat of the ſun, a flat piece of ground is banked in near the ſea, ſo as to let in the tide of flood and prevent its return; this is divided into ſeveral apartments communicating with each other. The ſea being admitted into the firſt of theſe, evaporates for ſome time and depoſits its impurities, after which it is paſſed into the ſecond, and the firſt apartment again ſupplied. The water undergoes a proceſs in the ſecond ſimilar to the former, and is then let into the third diviſion whoſe ſides and bottom are made of very firm and compact clay. Here the cryſtals of ſalt begin to form; and as they are formed they are broken and fall to the bottom, and when in ſufficient quantity they are taken out and put in heaps to dry: this ſalt is called *bay-ſalt*, and by the French, *gabelle*. In England they evaporate by artificial heat in large ſhallow iron boilers, ſtrengthening the brine with *rock-ſalt*. The cryſtals are taken out in baſkets; this is called *white-ſalt*. But although the ſun's heat in theſe climates be not ſtrong enough to carry on the evaporation to the point of cryſtallizing, it may however in very warm weather be employed to advantage for concentrating the ſalt; becauſe the vapour which is exhaled being freſh, the remaining brine muſt be more ſtrongly impregnated with the ſalt. It is upon a ſimilar principle they freeze the brine in very cold countries, for the ice is freſh and of courſe the ſalt concentrated. All that is evaporated by theſe means is ſo far a ſaving of expence and fuel. In ſome parts of France, they waſh the ſand of the ſea-ſhore, which contains ſome portion of ſalt, and evaporate this brine in leaden boilers; the quantity of water uſed to waſh the ſands ſhould be no more than what is merely ſufficient to diſſolve the ſalt in them. In order to aſſiſt the evaporation from ſalt-waters, the water is ſometimes conveyed by pumps into an apartment, at the top of a building made for the purpoſe, from which it is made to fall upon faggots placed on planks ſuſpended below the open floor of the apartment; thus preſenting a very large and divided ſurface, which always aſſiſts evaporation.

Sea-ſalt brine-ſprings and rock-ſalt, all contain, beſide common ſalt, calcareous, earth, magneſia. Epſum ſalts, Glauber's ſalts and eſpecially Gypſum, &c. To purify ſalt from theſe improper matters, a conical veſſel turned with its narrow and cloſe end downward, and bored with holes through the ſides, is made uſe of. This is nearly filled with ſalt, and boiling water ſaturated with ſalt is poured in, which will diſſolve and carry off the impurities (except Gypſum) leaving the ſalt behind. The reaſon of which is, that the heat is a powerful ſolvent of thoſe foreign ſaline matters, but not ſo of common ſalt; whence the boiling water will quickly take up the former, and holding them in ſolution bear them away in its courſe, while the common ſalt ſet free will precipitate and remain, thus at once increaſing and purifying the maſs. The Dutch are ſaid to prepare a ſalt for pickling herrings in a manner ſuperior to that of all other nations: The chief ſecret of this conſiſts in evaporating brine made from a ſolution of bay ſalt, in the gentleſt manner; and mixing with it a proper quantity of ſour whey, which unites itſelf to an uncombined fixed alkali, that is generally found among the impurities of ſalt.

A few obſervations concerning the waters of the ſea will not be thought unſeaſonably connected with this ſubject, and firſt, as to the cauſe of their ſaltneſs. Some are of opinion that this is owing to the ſalt carried into the ſea with the courſe of rivers; which ſalt not being ſubject to be raiſed from the ſea by evaporation, accumulates in a long courſe of ages. But beſides other objections to this theory, there is one inſuperable. It can be ſhewn by ſatisfactory calculation of the quantity of water contained in the ſea and poured into it by the rivers, joined to the proportions of ſalt contained in each kind, that all the rivers in the world could not from the creation of it have conveyed into the ſea more than about the ſeventeenth part of the ſalt which is contained in it. Others have derived it from beds of ſalt contained at the bottom like the mines of rock ſalt found near the ſurface of the earth. They ſeem to be of an opinion quite contradictory to the former, for they maintain that nothing but ſuch a maſs of ſalt could prevent the ſea from becoming freſh by the influx of rivers. But this conjecture is built upon a falſe foundation. For ſuppoſing the rivers contained no ſalt, and that they returned all the water which is raiſed from the ſea by evaporation, the ſaltneſs would ſtill continue the ſame. But rivers do contain a portion of ſalt, and they do not reſtore to the ſea all that is carried off by evaporation: on both which accounts its ſaltneſs ſhould rather increaſe than diminiſh. Others ſeem to unite theſe two ſuppoſitions, but have not ſupported their opinion with evidence ſufficiently convincing. After all the queſtion perhaps may not admit of a ſolution, for there is no reaſon to hinder us from ſuppoſing, that the waters of the ſea might have been originally formed in their preſent ſtate.

The next obſervation relates to the manner of procuring freſh water from ſea-water This can be done either by freezing or diſtilling. It has been already mentioned that ſea-water is in very cold countries expoſed to freeze, for the purpoſe of concentrating the ſalt in the remaining water: the ice being always found freſh, and therefore when diſſolved affording a ſupply of freſh water. The proceſs by diſtillation is to employ a gentle heat; for this will be ſufficient to evaporate the water, yet leave the ſalt behind. Dr. Irving's method is to apply a tube of tin to a hole in the lid of a common kettle uſed for boiling ſhip's proviſions: the tube has an inclination downward like the ſtem of a tobacco pipe, and is kept continually wetted with a mop to cool and condenſe the vapour, which has been driven over from the kettle, into water: and this falls into a hogſhead. If this method be employed for the purpoſe of ſaving fuel, by combining the proceſs with the boiling of the proviſions, it is certainly ſo far highly beneficial: and it is probable that the freſh water ſo procured though perhaps containing ſome ſalt, from the heat being a little too ſtrong, is yet ſufficiently pure and wholeſome.

CHAP. VI.

Of other Acids,

TO this conſideration of the three principal acids, a few remarks may be ſubjoined upon others of leſs note; as the Acid of Borax, the Phoſphoric Acid, the Sparry Acid, and the Acid of Amber.

Borax is a ſalt which comes from the Eaſt. It is dug up from the bottom of Salt Lakes in a cryſtallized form, and is of a dull white, or greeniſh colour. When this ſalt is analyzed, it is found to contain mineral Alkali united to an acid. For if boiling water be ſaturated with the ſalt, and a conſiderable quantity of ſulphuric acid be added to the ſolution, Glauber's ſalt is formed by the combination of this acid with the alkali, while a ſcaly ſalt is found ſwimming on the ſurface. And if this laſt ſalt be combined with mineral alkali, it compoſes a ſalt poſſeſſing the ſame properties with Borax. The Acid of Borax is ſometimes called *Sedative Salt*. The chief uſe of Borax hitherto known is to ſerve as a flux to vitrify different earths, being a ſalt of a very fuſible kind.

Phoſphorus is a ſubſtance very much reſembling ſulphur, but much more inflammable. At ſo moderate a heat as 60° of Farenheit it burns with a weak flame, which affords no ſenſible warmth; having the appearance of white fumes by day light, but conſiderably luminous in the dark. If it is contained in a veſſel which is ſurrounded by water heated to 160°, it takes fire and burns with a ſtrong flame.

Phoſphorus abounds in the mineral, vegetable and animal kingdoms, particularly in this laſt: and it is for the moſt part obtained from urine, bones, &c. Bones contain this acid in combination with calcareous earth: for if they be pounded, and a quantity of ſulphuric acid be poured on them, leſs than ſufficient to diſſolve the whole maſs, part will become Selenite by the union of the ſulphuric acid and lime, while the phoſphoric acid being diſengaged from its baſe, and being evaporated to dryneſs from the water it has taken up, appears in the form of a white or tranſparent glaſs. And if this glaſs be pounded and diſtilled with one third of its weight of charchoal the product will be phoſphorus, a little impure from a ſmall mixture of calcareous earth with its acid.

Phoſphoric acid may in its turn be obtained from phoſphorus by combuſtion, as ſulphuric acid is from ſulphur; or by means of the nitrous or ſulphuric acids which have a ſtronger affinity to its baſe; or by a ſtream of vital air, if the phoſphorus be melted in water. Phoſphorus takes fire ſo readily, that it is found neceſſary to keep it in a bottle of water. In handling it under the water, care ſhould be taken, that no part ſtick to the hands, or get under the nails: for the moment it comes into contact with air, it will take fire at a moderate temperature. The ſame principle of inflammability accounts for the luminous appearance made by writing with phoſphorus: which ſhould be done gently and ſlowly leſt the phoſphorus take fire; and water ſhould be at hand to extinguiſh it ſhould this happen.

Phoſphorus has hitherto proved of little important ſervice.

Amber is a brittle ſubſtance, for the moſt part of a yellowiſh colour, and ſometimes tranſparent. When rubbed it becomes electric and attracts ſtraws. It is inflammable with exceſs of air, and by diſtillation with a gentle heat in cloſe veſſels affords a ſmall portion of water, a ſublimate which is the acid of Amber, and an oil. The acid muſt be purified by repeated ſolutions and cryſtallizations. Amber is dug out of the earth in large quantities, under ſands, particularly on the ſea ſhore. Inſects are ſometimes found within it, which ſhews it to have been in a liquid ſtate. Its origin is yet uncertain. By ſome it is thought a mineral ſubſtance: by others a vegetable ſubſtance from its being found in the neighbourhood of foſſile Wood, and from other circumſtances; the moſt general opinion is that it is a reſinous juice of trees hardened by length of time, and mixed with vapours of ſalts and minerals under the earth.

Amber takes a very fine poliſh, and is employed in making vaſes, ſnuff boxes, trinkets and ſuch like. Two pieces of it may be united, by heating them, when moiſtened with oil of tartar.

Fluor Spar, called alſo Derbyſhire ſpar is a ſubſtance, which conſiſts of an acid united to calcareous earth. The acid is procured from it, by diſtilling it with half its weight of ſulphuric acid with a gentle heat; the retort had beſt be of lead or ſome other metal, becauſe this acid has the property of diſſolving glaſs and other ſiliceous earths; and a little water ſhould be in the receiver. Etchings are made in glaſs by the acid. Spar is made into various beautiful utenſils and ornaments, ſuch as Vaſes, Urns, Cups, &c. &c. There are ſeveral other acids mentioned by chemical writers: but to examine each would exceed the limits preſcribed to this work. Metallic and vegetable acids ſhall be examined in their proper places.

It deſerves to be remarked here, that the affinities between acids and alkalies are very different, according to the different ſtates, in which they are preſented to each other, whether liquid, ſolid, or aerial. In the liquid ſtate, the ſulphuric acid is moſt powerful, and the acid of borax leaſt ſo of all except tartar. Yet in the ſolid form, as when a combination of ſulphuric acid and an alkali is mixed with acid of borax, and the mixture well dried, the acid of borax ſhews a ſtronger affinity to the alkali than the ſulphuric, which is driven off by a ſtrong heat, while the other remains. In the aerial form the marine acid is moſt powerful, and the ſulphuric leaſt. But this laſt acid, it ſhould be obſerved, cannot be kept in the form of vapour without being combined with ſome inflammable ſubſtance, which weakens its force.

CHAP. VII.

Of Neutral Salts, with the Effects of Solution and Evaporation on the Temperature.

NEUTRAL SALTS are thoſe which are ſo compounded of acids and alkalies, as that the properties of one ſhall not predominate over thoſe of the other: or in other words, it is a compound which does not itſelf poſſeſs any of the diſtinguiſhing properties of either acids or alkalies. Neutral ſalts are neither ſour nor cauſtic; they do not effervefce with acids, nor do they change the colour of vegetables, as of ſyrup of violets. The principal of theſe have been mentioned in the courſe of the work, ſuch as common ſalt, Glauber's ſalt, ſalt-petre, tartar, ſal-ammoniac, and others. Beſide theſe, which have the alkalies for their baſes, other ſubſtances are called neutral ſalts, which conſiſt of an acid combined with other baſes, as earths and metallic ſubſtances; ſuch are calcareous nitre, formed by the combination of nitrous acid with lime; Epſom ſalt, the combination

tion of vitriolic acid with magneſia; alum, the combination of vitriolic acid with clay, &c. But the particular examination of theſe ſalts not falling within the deſign of this work, we ſhall paſs on to enquire into the effect of the ſolution of ſalts upon the temperature.—During the ſolution of ſalts in water, heat is ſometimes produced, but moſt commonly cold.—Fixed alkaline ſalts, Glauber's ſalts, and white vitriol, or the combination of vitriolic acid with zinc, give out ſmall degrees of heat during their ſolution.—Sea-ſalt, ſalt-petre, ſal-ammoniac, produce different degrees of cold:—thus if you ſaturate equal portions of water with theſe three ſalts, the quick-ſilver in the thermometer ſinks, in the firſt ſolution, two degrees; in the ſecond ſeventeen; and in the laſt twenty-ſix below it's former height in water, which laſt is the greateſt degree of cold cauſed by any ſalt hitherto known.

By means of ſal-ammoniac water may be frozen in ſummer, when the quick-ſilver ſtands at ſeventy degrees in Farenheit's thermometer—for in a tub let there be included a bucket, narrower and a little taller, and within the bucket a flaſk, the mouth of which riſes above the rim of the bucket; and let all the veſſels be filled with water heated to ſeventy degrees—ſaturate then the water in the tub with ſal-ammoniac, and the temperature of the water in the bucket will, by its communication with the cold produced in the tub fall conſiderably, ſuppoſe to about fifty degrees: let then this water in the bucket be ſaturated with ſal-ammoniac, and the temperature of that in the flaſk will in the ſame way fall ſome degrees below the freezing point, and conſequently will be frozen. In all theſe caſes, the cold is produced only during the time of the ſolution—the water recovers the temperature of the atmoſphere ſooner according as its quantity is leſs and its ſurface greater. There is a very ſtrange and unaccountable effect obſerved, in mixing nitrous acid with ſnow, and again with ſnow-water—when mixed with ſnow-water, it excites a conſiderable degree of heat; and when mixed with ſnow, it produces the greateſt degree of cold that has ever been yet obſerved.

Cold is alſo produced by the evaporation of water, and other fluids, which may be conſidered as an effect of the ſame kind with thoſe now mentioned; as it has been ſhewn before, that evaporation is truly a ſolution of water in air.

In dry weather a thermometer was put into water, which had been heated to eighty-ſeven degrees of Farenheit, by ſtanding expoſed to the direct rays of the ſun—it was then taken out, and its bulb held oppoſite to the ſun, which ſhone very bright: as the bulb grew dry by the evaporation of the water, the quickſilver in the tube fell very faſt till it came to ſeventy-ſix degrees. It there continued at a ſtand for a moment, and then roſe rapidly to ninety degrees; from the fall it appears that eleven degrees of cold were produced by the evaporation, and from the ſudden riſe, that the cold ceaſed the moment the evaporation was over. Again the thermometer was put into water, and ſtood at fifty degrees, while the temperature of the air in the ſhade was ſixty-eight degrees. Upon taking it out, the quickſilver, inſtead of ſinking by evaporation, began to riſe immediately from the effect of the warm air: it was then put into water heated to fifty-five degrees: when taken out the quickſilver ſtood for a time, and then began to riſe—it was then put into water heated to fifty-eight degrees, and when taken out the quickſilver fell three degrees before it began to riſe. From theſe experiments it ſhould ſeem, that fifty-ſix or fifty-ſeven degrees was about the degree of temperature of water at which the cold produced by the evaporation was compenſated, or balanced, by the heat of the atmoſphere at ſixty-eight degrees of Farenheit. The degree of cold produced by evaporation, appears to depend on the quickneſs with which the evaporation is made; and for this reaſon, the evaporation of water of a given temperature muſt be influenced by the ſtate of the air and the weather; by the degree of warmth and dryneſs; by the wind, which has a powerful effect in the proceſs, and by other cauſes leſs known.—And upon the ſame principle, ardent ſpirits, wine, ether, and many other fluids, produce greater cold by evaporation, as being more quickly evaporated.

It is common with the labouring people, in the height of ſummer, to drink large quantities of beer and porter, which for the moſt part goes off by perſpiration. The cold produced by the evaporation of the ſweat helps to keep the body cool—and thus has providence contrived to render the heat of the torrid zone more tolerable, by making that heat, by means of evaporation, produce a coldneſs on the ſurface of the body. When water falls from a conſiderable height, it is much ſooner evaporated by being ſeparated, than if it had continued entire, becauſe it preſents a larger ſurface to the air. And hence artificial caſcades may probably be of ſervice, not only in producing a gentle motion of the air, but likewiſe by cooling the air itſelf.

Wine is frequently cooled by wrapping wet cloths round the bottles, and expoſing them to the air and wind; this is explained by evaporation producing cold, as in the former inſtance. There is a great variety of other facts of a ſimilar nature, but thoſe already mentioned are ſufficient to ſhew what was intended, and to lead us to an application of the principle in different caſes.

SECT. III.

Of Metallic and ſome other Mineral Subſtances.

CHAP. I.

Of Metals.

METALS are heavy, opake bodies, having a conſiderable degree of ſplendour, and capable of being fuſed or melted with heat: many of them are malleable, *i. e.* may be extended by the hammer. They are for the moſt part found in mountainous diſtricts, lying in Strata called *Veins*, which in theſe ſituations are generally ſo diſpoſed as to be much more eaſily diſcovered than in plains, where they lie level. It is alſo a great deal eaſier to work the *mine* or pit made to extract them, in the former than the latter ſituation; becauſe drains can be more conveniently had for drawing off the water, and avenues made for going in and out of the mine.

Metals are generally mixed with earthy and other ſubſtances called *Ores*. Theſe ores are extracted by ſinking perpendicular pits called ſhafts large enough to let the workmen deſcend, and to raiſe the ore. For this laſt purpoſe axles are placed above the pits, with buckets hanging to their ropes. If the ore ſhould lye too deep for one ſhaft, an horizontal gallery is made, at the end of which another is ſunk; and ſo on, till they reach the bottom. Sometimes too they work the mine laterally or through the ſides of the gallery, if the ore be found in ſufficient quantity at that depth. The mines ſhould be well propped and ſecured with beams of timber, to prevent their falling in.

The two great obſtacles to the working of mines are noxious airs, and water. To obtain pure air, air-holes are pierced from top to bottom; or if this cannot be conveniently done, other methods are reſorted to, ſuch as kindling fires above ſome of the pits, which rarify the air, and ſo produce a more free circulation. But great care muſt be taken to place the fires ſo as there ſhall no danger of their diſengaging the vapours of fixed and inflammable air often found in mines. To remedy the inconvenience ariſing from water, outlets are made, where the level of the ground will admit: and hence appears one great advantage of having the mine on the ſide of a mountain. Should this method not anſwer for carrying off the whole water, it is raiſed by pumps or moſt generally by the ſteam-engine to ſuch a level, that an outlet can be obtained.

The number of metals already diſcovered are 21. They are found in one or other of four different ſtates: firſt, native or pure, in their metallic ſtate, either alone or combined with each other: ſecondly, mineralized, or combined with ſulphur or arſenic, ſo as not to poſſeſs their properties, till ſeparated from theſe: thirdly, in the ſtate of calces: fourthly, combined with acids.

The general method of eſſaying ores, in the dry way, is firſt to reduce them to a very fine powder, which is beſt done by expoſing them to a very ſtrong heat, and then throwing them into cold water. This ſudden tranſition makes them crack and fall to pieces, after which they are more eaſily pounded: ſecondly, the lighter parts of this powder are waſhed away from the reſt in ſhallow troughs, by agitating and ſtirring the water, and then pouring it off before they have had time to ſubſide; thirdly, the volatile parts are driven off by roaſting; Fourthly, the ores are then melted in furnaces with charcoal, ſalt of borax, alkalies, and other ſubſtances which are apt to run into glaſs, while the metal in a melted ſtate falls to the bottom. In this laſt proceſs, which is called *Smelting*, the metal, which in the ore is generally calx, becomes reduced or revived into the metallic ſtate. For it either receives phlogiſton from the more combuſtible matters, or, according to the new theory, gives out to them its vital air; the glaſſy ſcum which floats on the ſurface, ſerving at the ſame time to prevent all communication with the outward air, by which means the proceſs of reduction ſucceeds better. They are ſometimes eſſayed in the humid way by the three principal acids, Sulphuric, Nitrous and Marine. Thus if upon 100 parts red ſilver ore, 500 of nitrous acid, previouſly diluted, be poured; and, when no more can be diſſolved even with the aſſiſtance of a gentle heat, the ſolution be decanted off, it is found to contain above 60 parts in 100 calx of ſilver. And if the reſidue be treated with ſtrong marine acid, part of it, to the amount of more than 21 parts, calx of antimony, is diſſolved: the remainder is found to be ſulphur. By ſimilar proceſſes other ores may be analyzed: as tin mineralyzed with ſulphur, by Aqua Regia, &c. &c. &c.

Metals are divided into perfect and imperfect. Perfect metals are ſuch as undergo no laſting change of their properties by the heat of common furnaces. Theſe are gold, ſilver, and platina. Imperfect metals are thoſe, which by ſtrong heat of fire are calcined: this is the caſe with all except thoſe three.

There is another diviſion ſometimes made of them into metals and ſemi-metals: the former being thoſe which are malleable, the latter not ſo or in a very ſlight degree. Mercury or quickſilver is by ſome chemiſts reckoned among the former kind, by others among the latter. It matters but little, for this laſt diviſion is at preſent ſeldom adopted.

Metals, gold excepted, are altered by the air, and generally in proportion to its moiſture: the effect is, that their ſurfaces are tarniſhed and covered with ruſt, which was formerly called the earth of the metal, but properly ſpeaking it its calx. The acids combine ſtrongly with them, but will not diſſolve them unleſs calcined by the acid itſelf, or preſented to it in that ſtate. This is proved from ſome of them being inſoluble in acids in the metallic ſtate, yet ſoluble by the ſame acids in the ſtate of calces.

If to the ſolution of a metal in an acid an alkali be added, the metal is precipitated in the form of a calx: but if inſtead of the alkali another metal be added, to which the acid has a ſtronger attraction than to the firſt, the firſt is precipated in its metallic ſtate. The reaſon of this laſt appearance is, that the new metal being more ſtrongly attracted by the acid, and therefore calcined rather than the other, it either parts with its phlogiſton, or takes up the vital air from the calx, and while it thus revives this calx, becomes itſelf calcined. The appearance here ſtated is not univerſal. Sometimes a metal precipitates another in the metallic ſtate with one acid, ſometimes as a calx with another, and ſometimes not at all from a third.

Metals mix with each other in a ſtate of fuſion; the mixture is ſometimes called in general an alloy; but this name is moſt particularly applied to expreſs a portion of baſer metal, ſuch as copper, tin &c. mixed with the precious metals, gold or ſilver. Metals, which melt nearly with the ſame degree of heat, may for that reaſon be blended together in various proportions of weight, but this is nothing more than a mixture: chemical combination takes place only when they are in one certain proportion. For inſtance gold does not chemically unite with ſilver, unleſs when its weight is to the weight of ſilver as five to one. There are ſome metals, whoſe parts readily unite with each other, and with thoſe of other metals. Many more do ſo with great difficulty, and ſome in no degree. Upon theſe properties is founded the uſeful art of ſoldering which conſiſts in joining two pieces of metal together by means of a thin plate of ſome other which is applied to each of them in a melted ſtate, and more eaſily combines with them than they can be made to do with each other. Thus tin is a ſolder for lead, and copper for iron. Metals are the beſt conductors of heat. By their opacity as well as ſplendour they are well calculated for reflecting light. Their uſes are too many and various to be here enumerated. It is ſufficient to obſerve, that they are the principal inſtruments and objects in arts, manufactures, and practical ſciences.

CHAP. II.

Of Gold.

GOLD is the moſt perfect and valuable metal yet known; of a reddiſh colour, without ſenſible taſte or ſmell. It is one of the heavieſt bodies in nature, its ſpecific gravity being more than nineteen times greater than that of water. Gold is but moderately hard and elaſtic, very malleable, and extremely ductile, or capable of being drawn out into length without a ſenſible ſeparation of its parts. Its great malleableneſs appears from the art of making gold-leaf: which is done by hammering thin plates of gold between fine ſkins or membranes, ſuch as ox gut. From a calculation of the weight and meaſure of the beſt leaf, it is found that one grain is made to cover more than fifty-ſix ſquare inches, and its thickneſs to be about the two hundred and eighty thouſandth part of an inch: in this ſtate it is tranſparent, tranſmitting light of a lively green. But its ductility in wire-drawing is more ſurpriſing. If a piece of ſilver be covered over with gold, and drawn into wire by forcing it to paſs through holes, continually leſſening in ſize, till it becomes ſo ſlender as to be fit for making lace, the gold covering adheres to the ſilver through the whole proceſs, ſo as completely to gild it in the laſt ſtate. This covering is but one-twelfth part ſo thick as the gold-leaf before mentioned: one ounce of gold can be made to cover a ſilver wire 1300 miles in length; in which ſtate it is in thickneſs about the three millionth part of an inch. Probably it may be owing to the ſame property that gold is ſo tenacious, that a wire of it one-tenth of an inch in diameter can ſupport a weight of five hundred pounds without being broken.

Gold is found for the moſt part in a native or metallic ſtate, although generally alloyed in this ſtate with ſilver, copper, iron, or all three. It is ſometimes found in the ſands of rivers, in the form of grains, at others in diſtinct lumps. In a mountain of the county of Wicklow, in Ireland, one lump was found, which weighed upwards of two ounces, of very pure gold. From South America the greateſt quantity is brought to Europe: ſome is imported from the Eaſt Indies and China, and ſome from the coaſt of Africa. The chief European mines are in Hungary.

When gold is found in ſands, it can be obtained by ſimply waſhing the ſands, for the lighter foreign ſubſtances remain ſuſpended, and are carried off with the water, while the heavy particles of gold ſink to the bottom. But when it is bedded in earths or ſtones, the ore is pounded in the ſtamping mill, and then waſhed: after which it is boiled in water, with about one-tenth of it's weight of quickſilver—in ſome time the quickſilver ſoaks up the gold, and the water being poured off carries away all the earthy particles—the mixture of gold and quickſilver is then ſtrained and preſſed through leather: this ſeparates them in a conſiderable degree; for the latter runs through, and the former remains behind. Any more quickſilver which is united to the gold, may be carried off by diſtillation, as being much more volatile; and the pure gold in a melted form may be run into bars, or ingots.—Theſe proceſſes are called *purification.*

If gold be alloyed with ſilver, it is purified by a proceſs ſometimes called *parting*, and ſometimes *quartation:* this laſt name is given on account of the proportion of materials employed; three parts of ſilver being added to the alloy, which of courſe makes a fourth part of the mixture. They are melted together, and flowers of ſulphur thrown in: the ſulphur combines with the ſilver, forming a dry black ſcum upon the ſurface; and the gold, with which the ſulphur has but little affinity, falls to the bottom. In the humid way gold is purified from ſilver by the nitrous acid, which rapidly diſſolves ſilver, but has very little action upon gold.—This laſt method is frequently uſed as a teſt, to eſſay the purity of gold.

Another method of eſſaying gold is, by the *touch-needles*, or ſmall bars of gold differently alloyed.—The gold to be tried is rubbed upon a fine black ſtone, and the colour of its ſtroke is compared with thoſe made upon the ſame ſtone with the touch-needles; whoſe compoſition or alloy being known, they indicate the alloy of the gold under trial; and it is ſaid to be of the alloy of that needle, whoſe ſtroke it moſt reſembles. But leſt this reſemblance ſhould deceive, in being merely an imitation of colour, a little nitrous acid is poured on, which will diſſolve the ſtroke of the metal on trial, more or leſs, according to the quantity of baſer metal mixed with pure gold.

If gold be alloyed with any of the imperfect metals, as copper, lead, &c. it is purified by the proceſs called *cupellation*, in the following manner: the alloyed gold is put with about twice its weight of ſilver, and ſome lead, into a crucible made of a very porous ſubſtance, ſuch as bones, and called a *cupel*—they are all expoſed to a conſiderable heat, which vitrifies the lead, or converts it into a kind of glaſs, enabling it likewiſe to form the ſame kind of ſubſtance with the imperfect metals in the alloy.—This glaſſy fluid ſoaks into the pores of the cupel, while the remaining mixture of gold and ſilver remains behind in the veſſel: the ſilver is then ſeparated from the gold as before, by parting.—It ſhould be obſerved, that every alloy of gold is ſuppoſed to be divided into twenty-four parts, called *carats*, and that the purity of gold is eſtimated according to the number of thoſe parts, which it makes up.

Gold does not ſuffer ſenſible alteration from air; neither is it changed in its properties by the fire of furnaces, but when cool reſumes its former ſtate—it is, however, calcined by a ſtrong burning lens, and is ſo far volatilized, that the vapour, which it diſcharges, is capable of gilding ſilver. In the metallic ſtate it does not unite with any of the earths, or ſalts; but in the ſtate of a calx it unites with flint, or glaſs, to which it imparts a purple colour.—The beſt means of calcining and ſolving gold, is with aqua regia—the ſolution is made with an effervеſcence, and is of a yellow colour, conſiderably cauſtic, tinges animal ſubſtances with a deep purple, and when carefully evaporated, yields fine golden cryſtals reſembling topazes.

This ſolution of gold in aqua regia, is decompoſed by the addition of lime, or magneſia; which by their greater affinity to the acid, precipitates the gold in the form of a yellow powder—by the fixed alkalies in the ſame form, unleſs the alkali be in too great quantity, for it then re-diſſolves the powder.—The precipitate from fixed alkali is a true calx, capable of being diſſolved by the vitriolic, nitrous, and marine acids, although gold in it's metallic ſtate is not ſenſibly affected by them.—Volatile alkali precipitates from the ſolution

tion of gold, a powder called *fulminating gold;* which explodes with a very ſlight degree of heat, and even with friction. If this powder be expoſed to a gentle heat, brilliant ſparks fly off before it explodes; the electric ſpark makes it detonate, but a ſingle ſpark of common fire will not kindle it, unleſs ſtirred. After exploſion part of the gold is found in the ſtate of a calx, and part in the metallic form; whence it ſhould ſeem, that it contained ſome combuſtible matter, probably an alkaline gas; which either by loſing phlogiſton, or attracting vital air, produced the partial calcination. So great is the force of fulminating gold, that when it is kindled upon a plate of metal, as upon lead, tin, or ſilver, it ſtrikes a hole through the plate: but it will not explode in cloſe veſſels.

Gold is precipitated from its ſolution by moſt metals. If tin be added, it ſeparates the gold in the form of a fine powder, called *purple precipitate of Caſſius*, which is much uſed in painting Porcelain, and enamel—it is beſt obtained by diſſolving tin in a diluted aqua regia, compoſed of two parts of nitrous, and one of marine acid, very ſlowly and without heat; and then by adding to this ſolution diluted with about one hundred times its weight of water, a ſolution of pure gold in three parts of nitrous, and one of marine acids: the precipitate is a combination of the calces of gold and tin.—Lead and ſilver precipitate gold from it's ſolution, in a deep purple powder: copper and iron ſeparate the gold in its metallic brilliancy.—Certain inflammable ſubſtances alſo revive it in the metallic ſtate; as eſſential oils, ether, and others, which form with it liquors called *potable gold.* — The eſſential oils hold it ſuſpended for a while, after which it ſettles on the ſides of the veſſel—the oil ſtill retaining a bright yellow colour; which, however, is not owing to any mixture of the gold, but to the action of the acid upon the oil.—Ether, by its action, abſorbs the whole gold from the ſolution: and having no effect upon any other metal, ſeems to be one of the beſt teſts for diſcovering the preſence of gold. Martial, or green vitriol, precipitates gold from its ſolution in the greateſt purity.

Gold combines with the greateſt part of the metals: with copper, which hardens and ſo renders it much fitter for ſeveral uſes, as for inſtance coin:—with iron, of which it takes up many times its own weight, and forms a compound metal ſuperior even to ſteel for cutting inſtruments:—with zinc, compoſing a metal of a fine grain, well ſuited to form the mirrors of reflecting teleſcopes:—with quickſilver in particular, forming with it mixtures called *amalgams*, which, among other purpoſes, are employed in gilding metals, in the following manner—the plate of metal to be gilded, being well cleaned and poliſhed, is immerſed into a weak ſolution of quickſilver in ſome of the acids;

the quickſilver precipitates, and covers the plate with a thin coating. An amalgam of gold and quickſilver is then ſpread with a bruſh over this coating, to which it cloſely adheres: the plate is heated, and the mercury driven off in vapour, leaving the gold adhering to the plate, which is then burniſhed.—This method is called *water gilding*, and ſometimes *gilding in or molu*.

Another manner of gilding is, by means of gold leaf, which is ſpread upon wood that has been previouſly ſmeared over with oil or ſize. A third way is, by ſteeping linen rags in a ſolution of gold, then drying and burning the rags: after which the end of a moiſtened cork is dipped in the burnt matter mixed with clean wood-aſhes, and is rubbed upon the metal to be gilded, which is for the moſt part ſilver. Porcelain, glaſs, and enamel, are gilt by means of gold powder mixed with diſſolved gum arabic, or oil, with a little borax: this mixture being laid on with a pencil, the ſubſtances on which it is laid are placed in a furnace or oven, where by a proper degree of heat it is burned in: the powder may be obtained in various ways; one of which is, by precipitating gold from its ſolution in the metallic ſtate, as by adding copper.

Beſide the uſes already mentioned, to which gold may be applied, either by itſelf, or in combination with the different metals, and other ſubſtances; a multitude of beautiful utenſils and ornaments are compoſed of it—but its chief uſe is, to ſerve as a coin, of all which it is far the moſt valuable, on account of its ſcarcity, weight, and untarniſhed brilliancy.—The gold coins of Great Britain conſiſt of eleven parts gold, and one copper: they are, therefore, gold of twenty-two carats.

CHAP. III.

Of Silver.

SILVER is a perfect metal, of a white and brilliant appearance, without ſenſible taſte or ſmell, of moderate ſpecific gravity, being about 10½ times heavier than water. It is malleable in the next degree to gold, capable of being beat out into leaf thinner than the fineſt paper, one grain covering above 50 ſquare inches: and ſo ductile as to be drawn out into wire, whoſe diameter is ſmaller than the fineſt hair, the wire for aſtronomical purpoſes being about the 750th part of an inch in thickneſs: its tenacity is ſuch, that a thread of it one tenth of an inch can ſupport a weight of 270 pounds without breaking. It is pretty hard and elaſtic, and is the moſt ſounding of all metals, copper excepted.

Silver is found in ſeveral ſtates in nature, 1ſt. native, diſtinguiſhed eaſily by its brilliancy. This is often in irregular maſſes of different ſizes, ſometimes in the form of fine twiſted threads, at others reſembling net work, and again in dendrites or the appearance of leaves: the ores in the rich mines of Potoſi are of this kind. The native ſilver is for the moſt part diſperſed in beds of quartz or ſtony earths, and alloyed with ſome other metal, frequently gold or arſenic. 2dly, The vitreous ore of ſilver, which is formed of ſilver and ſulphur: This is found in the mines of Germany and Hungary, is of a darkiſh grey colour reſembling lead and is ſoft enough to be cut with a knife. It yields from 70 to 80 pounds of ſilver in a hundred weight. 3dly, Calciform or red ſilver ore, ſometimes in maſſes, ſometimes diſperſed through other minerals. Its colour is a dark red, and its luſtre metallic; when broken, the appearance is that of ſmall needles converging to a point. This ore yields about 60 pounds of ſilver in the hundred weight. 4thly, The horn ore, or the combination of ſilver calx with marine acid. It is ſometimes nearly in powder, ſometimes cryſtallized in cubes, its colours are various, and when expoſed to the light it becomes brown. The ſeveral ſpecies of theſe ores contain other metallic matters, as cobalt, nickel, copper, and antimony: that, which contains the laſt kind, is called the plumed ore of ſilver. Silver is likewiſe found, though in ſmall quantities, in ores of lead, tin, copper &c. &c.

Silver ores are eſſayed in the humid way by the acids; of which an inſtance was given in a former chapter. In the dry way, the proceſs is pretty much the ſame with the manner of extracting ſilver from its ores in the large works as follows.

Native Ores of Silver are triturated or ground very ſmall with quick-ſilver which diſſolves and combines with the ſilver, without touching the earthy ſubſtances. The amalgam or mixture is then waſhed, to ſeparate any foreign matters from it, and is afterwards ſtrained and preſſed through leather: it may be further purified by diſtillation, as was done with gold. The ſilver is melted into bars or ingots.

Sulphureous Ores of Silver are roaſted, and then melted with lead, borax, or ſome other flux, to aſſiſt their fuſion. By the firſt operation the ſulphur is driven off, and by the ſecond the ſilver is obtained, though for the moſt part alloyed with the imperfect metals, lead, copper, iron, &c. Theſe are afterwards ſeparated by cupellation, of which an account has been already given. As the refining of the ſilver goes on in this proceſs, the metal becomes more and more brilliant, till at laſt it exhibits a flaſh, at which moment the refining is known to be completed, and the proceſs is ſtopped. The ſilver is then free from the imperfect metals, but may contain gold. If this be the caſe, the perfect metals may be ſeparated by parting, as mentioned before. Sometimes ſilver is ſeparated from the copper combined in its ore, by melting the alloy with lead, which unites and flows off with the ſilver leaving the copper behind. *Poor Ores of Silver* are fuſed, without any previous roaſting, along with a certain quantity of pyrites, and afterwards undergo cupellation with lead.

Silver ſuffers no ſenſible change from the atmoſphere, nor from the action of water; but when expoſed to animal exhalations is covered over with a cruſt which is found to conſiſt in part of ſulphur; a ſubſtance probably contained in that noxious air that is diſcharged from the lungs.

Silver, though not altered by the heat of common furnaces, is calcined by a burning Lens; and in the twentieth fuſion with the heat of a porcelain furnace it was vitrified by M. Macquer, and a glaſs of a greeniſh colour obtained.

Sulphuric acid will not diſſolve ſilver; unleſs the acid be concentrated and boiling, and the ſilver divided into very ſmall parts: neither will the marine, unleſs it be dephlogiſticated. But the nitrous acid diſſolves it with great rapidity, even without the aſſiſtance of heat: and if the ſilver be pure, the acid loſes its blue or green colour, and becomes tranſparent. When any gold is contained in the maſs, it is ſeparated in a kind of ſmall flocks, which collect at the bottom. The nitrous acid diſſolves more than half its weight of ſilver. This ſolution corrodes the fleſh of animals, and ſtains vegetable matters as well as ſeveral kinds of ſtones, alſo hair, bones, and other animal matters. It is ſometimes uſed to mark linen for the bleach field; and the proceſs of bleaching encreaſes the ſtrength of the colour; which is owing to the action of the ſun's light upon the metal in the acid; for if any part remain in the ſhade, it becomes colourleſs. If this ſolution be evaporated, it yields flat cryſtals, called *Nitre of Silver*, or *Lunar Nitre:* which placed upon a burning coal, detonates, and leaves a white powder that is pure ſilver.

Nitrous Solution of Silver is decompoſed by lime and the alkalies: and alſo by the ſulphuric and marine acids, notwithſtanding the great difficulty with which they combine with ſilver. By means of the ſtronger affinity of theſe, nitrous acid can be purified from them, by pouring into it ſome nitrous ſolution; the ſilver ſeizes upon the ſulphuric or marine acids, and precipitates with them to the bottom, leaving the nitrous acid pure. The ſolution is likewiſe a teſt of theſe acids in waters upon the ſame principle; and a few drops of it will occaſion a cloud, if the acids exiſt in them. The precipitate, formed by marine acid from the nitrous ſolution of ſilver, is called *Luna Cornea*, from the appearance which this ſalt has, when fuſed on a gentle fire.

A mixture of ſtrong ſulphuric with nitrous acid diſſolves ſilver, yet does not act upon the other metals. This is an uſeful diſcovery for all caſes where it may be neceſſary to ſeparate ſilver from thoſe metals; for inſtance where copper is plated, the cuttings that remain, and pieces otherwiſe uſeleſs may be thus turned to conſiderable advantage.

If to the nitrous ſolution of ſilver be added ſome lime water, the metal is precipitated in the form of a calx; which mixed and agitated with volatile alkali, and afterwards dried, is the powder called *Fulminating Silver.* The properties of this powder are aſtoniſhing, it fulminates without heat or even friction, and merely with the touch of any other ſubſtance. Not more than a grain will admit an experiment without danger; and even that quantity muſt be approached with the face maſked, and the eyes guarded by ſtrong glaſſes.

Moſt metallic ſubſtances decompoſe the nitrous ſolution of ſilver. Quickſilver ſeparates the ſilver in its metallic ſtate; the precipitation is made very ſlowly, during ſome weeks, exhibiting at laſt a curious and beautiful arrangement called *Arbor Dianæ* or the *Tree of Diana.* This is nothing more than a cryſtallized amalgam. Copper likewiſe precipitates ſilver in the metallic ſtate: one part of the former will precipitate three parts of the latter in a pure ſtate, yet with a very ſmall portion of copper mixed with it, an effect ſimilar to what happens in moſt precipitations.

Silver is not altered by the action of the neutral ſalts, as nitre. And hence we are furniſhed with a method of purifying it from the imperfect metals, which happen to be united with it, viz. by fuſing the alloy in conjunction with nitre: for the nitre detonates, and calcines the imperfect metals, while the ſilver is found at the bottom freed from them, and much purer than before.

Silver is acted upon by combuſtible matters, as by ſulphur, which combines with it, and forms a true artificial ore. It is tarniſhed by inflammable ſubſtances, as appeared already from the ſulphureous cruſt found on its ſurface. It unites alſo with arſenic and antimony, compoſing with each of them a brittle alloy. We have ſeen before, that it is often united in nature with gold, copper, and other metals: ſimilar combinations can be effected by fuſing them together. But quickſilver diſſolves it completely even in the cold, and becomes in ſome meaſure fixed by this combination. Tin deprives ſilver of its ductility, and lead renders it more fuſible, leſs ſounding and hard.

Silver is of various uſes, it ſerves as a beautiful ornament by its brilliancy; as an uſeful coin by its ſplendour and hardneſs; as applied upon the ſurface of different bodies by way of plating, for inſtance copper, which can be covered by an amalgam of ſilver in the ſame manner, that it is gilded, as was ſhewn in the laſt chapter. Stuffs are wrought, and lace made with this metal: it forms a great variety of veſſels and utenſils; table ſilver is generally alloyed with one twenty fourth part of copper, and coin with about one twelfth.

CHAP. IV.

Of Platina.

PLATINA is a perfect metal, heavier than all others, having a ſpecific gravity twenty-two times that of water; of a whitiſh appearance, between thoſe of lead and ſilver, and without taſte or ſmell. It is malleable in a pure ſtate, and ductile; but to what degree is not yet known: —a wire has been drawn nearly the two thouſandth part of an inch in diameter, ſtronger than one of gold of the ſame ſize.

Platina is generally found in ſmall grains, among the gold mines of Spaniſh America, which grains are conſiderably malleable; but when a number of them are collected together, they can hardly be ſo perfectly fuſed as to be all equally malleable. It cannot be melted by the moſt violent common fires; but may be fuſed by the heat of a burning lens, or the flame of charcoal urged by vital air. When pure, its parts adhere together by hammering in a white heat: a property confined to this metal and iron.

Platina is not altered by expoſure to the air: a property which would render it valuable in the conſtruction of reflecting mirrors.—It is not acted upon by the ſimple acids, but is diſſolved in aqua regia: the ſolution is firſt yellow, and afterwards a reddiſh brown, cauſtic, and tinges animal matters with a dark colour: it is decompoſed by ſal-ammoniac, and precipitated in the metallic ſtate.—Hence a compound ſolution of gold and platina in aqua regia may be ſeparated, by adding martial vitriol, which gives the former, or ſal-ammoniac, which gives the latter. Metallic ſubſtances precipitate platina from its ſolution, but generally in the ſtate of a calx.

Platina unites with moſt metals: but theſe combinations having hitherto been applied to little uſe, it will not be neceſſary to dwell on them particularly.

CHAP. V.

Of Copper.

COPPER is an imperfect metal, of a reddiſh brown and ſhining colour, a nauſeous taſte, and diſagreeable ſmell when rubbed or heated; having near nine times the ſpecific gravity of water. It is hard, ſonorous, and malleable, and ſo ductile and tenacious, that a wire one-tenth of an inch in diameter is able to ſupport near three hundred pounds weight without breaking.

Copper is ſometimes found native, yet moſtly impure even in this ſtate; at others in the ſtate of a calx, united with other ſubſtances.—The chief kinds are as follow; ores which contain ſulphur, among which are the vitreous copper ore, of a red, brown, blue, or violet colour, uſually ſo ſoft as to be cut with a knife. The grey copper ore is a combination of ſulphur and arſenic with copper, iron, and ſilver, heavy and hard to be melted. Blendoſe, or brown copper ore, hard, ſolid, and granulated, contains the metal with ſulphur, arſenic, zinc, and iron.—Mountain green is a calx of copper, of the colour of verdigris: mountain blue is alſo a calx of a deep blue colour, contains ſometimes a mixture of lime, and is almoſt in a ſtate of powder.—Some ſlates, and one ſpecies of coal, afford copper; and ſeveral waters contain this metal diſſolved in acids.

Copper ores are treated in the large way, much in the ſame manner as they are eſſayed—the ores are pounded and waſhed; after which they are roaſted in the open air with a little fuel, to drive off the ſulphur—the remaining impure ore is roaſted ſeveral times, till at laſt black copper, which is malleable, is obtained—with this is fuſed about three times as much ſtrong flux, and the mixture is moulded into what are called loaves of liquation, which being placed over a fire, the lead contained in them fuſes, and carries down with it the precious metals:—the copper remaining behind is again fuſed, and all the impure matters ſeparated in the form of a ſcum, which is carefully removed. In the great Hungarian mines, the copper is expoſed to the fire fourteen times before the work is completed.

In the Iſle of Angleſey the ore, after being roaſted, is waſhed in water, and pieces of cold iron are alſo thrown into it; which afford ſome ſmall quantity of copper, in addition to what is procured as above.—The changing of iron into copper, as it is called, is nothing more than this—moſt copper ores contain ſulphur, whoſe acid uniting with the copper forms blue vitriol, or copperas: the water, which iſſues from the mine, diſſolves, and becomes impregnated with this ſalt; but this fluid having a ſtronger attraction to iron than to copper, when a bar of the former is put into it, the copper is precipitated from the ſolution into the place of the iron, which is diſſolved. There are celebrated copper mines near Arklow, in the county of Wicklow, whoſe waters are as profitable as the ore. Pits are made, and ſoft iron bars laid in the water: the iron bars are ſeen covered with a thick coat of copper, into which they may almoſt be ſaid to be changed, and a coppery mud is found in the bottom of the pits. One ton of iron produces near two tons of copper mud; and each ton of this, when melted, yields about ſixteen hundred weight of copper, which is much more valuable than the ſame weight fluxed from the ore.—The method of changing iron into copper, was accidentally diſcovered at theſe mines by a workman, who had miſlaid his ſhovel, but ſome weeks after found it in the copperas water, ſo encruſted with copper, that the metal was thought to be changed.

Copper is found in many other parts of the world, in Spain, France, England, Norway, Hungary, Sweden, and elſewhere. Japan copper is thought pureſt of any, and Swediſh beſt for wire drawing. Paris mountain, in the iſle of Angleſey, contains a bed of ore forty feet thick, and is ſaid to produce upwards of four thouſand tons of copper yearly.

If copper be expoſed to fire of a moderate heat, the poliſhed ſurface, like ſteel, puts on different colours, reſembling the colours of the rainbow, red where moſt heated, and violet where leaſt. It does not melt, till it has been for ſome time red; and when in fuſion is covered with a green flame. If it be let off at the bottom of the veſſel, while the upper ſurface cools, it cryſtallizes on the ſides of the veſſel. This metal, reduced to fine powder, and thrown acroſs a flame, gives it a blue or green colour: it is on this account employed in fire-works.—The calx of copper may eaſily be obtained, by heating it's ſurface in the open air, and then hammering it, or quenching it red hot in cold water, a calx of a blackiſh red falls off in the form of ſcales, called ſcales of copper.

Copper ruſts in the air: but the corroded part is very thin, and ſerves to protect the reſt of the metal from further corroſion. It does not ſeem to be much affected by water, unleſs this be in the ſtate of vapour; and, therefore, it is much more dangerous to let liquors cool in copper veſſels, than to boil them. In the latter caſe, the vapour is driven off by the force of heat, but in the former, it reſts upon the ſides of the veſſels and corrodes them.

All the acids act upon copper: the nitrous acid rapidly, and without the aſſiſtance of heat, forming with it a metallic ſalt.—If this ſalt be laid upon tin foil, and the tin foil be inſtantly folded up, nitrous vapours ſoon iſſue forth, afterwards the tin crackles and flames, and is reduced to a grey calx. — Sulphuric and marine acids act upon copper, when they are concentrated and boiling. The former affords blue vitriol: but the vitriol ſold in the ſhops is made by roaſting the copper pyrites, or by cementation, that is heating plates of copper in layers of ſulphur; in both caſes the ſulphuric acid, being diſengaged by fire, acts upon the copper, and diſſolves it.—The marine acid forms with copper a ſalt of a fine green colour, which diſtinguiſhes it from the two foregoing.—Acids of vegetables alſo diſſolve copper, as may be ſeen from the manner of making verdigris, (which is a calx of copper) as follows—the huſks of grapes, and other refuſe, which remain after preſſing the juice, are ſpread upon plates of copper, and reduce their ſurface to a calx. This is afterwards diſſolved in vinegar; the ſolution diſtilled, and cryſtals obtained: it is uſed as a paint.

Copper unites well with ſulphur—if equal parts of copper filings and flowers of ſulphur be heated red hot in a crucible, they form a coarſe greyiſh maſs, which is more fuſible and brittle than copper itſelf: this compoſition is uſed for dyeing and painting Indian ſtuffs.—Another preparation of copper is employed to colour enamels: it is obtained by throwing ſome fine copper filings upon nitre in fuſion, the copper being hot; a ſlight motion attended with flaſhes takes place, the copper is calcined, and the calx, after waſhing away the fixed alkali, fuſes into a deep green, which it imparts to the enamel.

Copper combines well with moſt metals: with arſenic it forms *white tombac.*—It unites with tin; as appears from the method of tinning copper, which ſhall be mentioned elſewhere; and alſo from the compoſition of theſe two metals in fuſion, called *bronze*, which is of much ſervice in making cannon, ſtatues, bells, &c. &c. It muſt be obſerved, however, that in making theſe, portions of lead, zinc, or arſenic, are likewiſe employed. The union of tin and copper compoſes excellent ſpeculums for reflecting teleſcopes: about half the quantity of tin in fuſion, is added to the melted copper.—With zinc alone, copper forms *braſs* in the following manner—the copper is reduced to very ſmall grains, by being paſſed in a melting ſtate through a perforated plate of iron, into a pit dug in the ground, and containing cold water, which muſt conſtantly be renewed, but ſlowly, to prevent an exploſion. Theſe ſmall grains of copper are mixed with calamine, which is the calx or ore of zinc, and expoſed with charcoal to a red heat in a furnace or crucible: when the maſs is heated to a ſufficient degree, the vapour of the reduced calamine, or zinc, penetrates the copper, and converts it into braſs—toward the end of the proceſs the heat is raiſed, and the braſs being melted falls to the bottom. Inſtead of ſmall grains, the copper is ſometimes applied in thin plates, which are cemented in calamine and charcoal. Theſe plates, when changed into braſs, are called *Dutch gold*, and are hammered out into leaves, about five times as thick as gold-leaf.—In good braſs the quantity of zinc is about one-third of its weight.—Braſs is free from ſeveral inconveniencies attending copper: it is more fuſible, more ductile, and tenacious, more eaſily manageable with heat, and leſs apt to ruſt by the action of air and moiſture.—In the large works forty-five pounds of copper, and ſixty of calamine, yield between ſixty and ſeventy of braſs.

Copper unites with ſilver, and may be *plated* with it thus—upon ſmall wedges of copper thin plates of ſilver are applied, and bound with iron wire, allowing about one ounce of ſilver for twelve of copper—a ſmall margin is left at the edges, and is covered with borax; which ſerves, when the whole is expoſed to a ſtrong heat, both to aſſiſt the melting of the ſilver, and to unite it in this ſtate to the copper—the copper wedges now united with the ſilver plates, are rolled under ſteel rollers, moved by a water mill, and afterwards by hand rollers, till they are brought to the required thickneſs and extent, according to the uſes for which they are deſigned. The thinneſt of theſe plates are applied to the lining of drinking horns—the thickeſt may be advantageouſly employed in lining ſaucepans, and other kitchen utenſils: for fire does not calcine ſilver.—One ounce of ſilver is, in this operation of plating, ſpread over a ſurface of about three ſquare feet.

There is another kind of plate, called *French plate;* which is made by heating copper, or rather braſs, to a certain degree, and by applying ſilver leaf upon the heated metal, to which it adheres by being rubbed with a proper burniſher. In ornamental works, which are not much handled, ten leaves are ſufficient: but this method is very unfit for other purpoſes, one hundred leaves not being enough to conceal the braſs for any time, if the plate be much in ſervice.

The uſes of this metal are too numerous to be diſtinctly ſpecified.—A great variety of theſe have been already ſtated, or alluded to: beſide which, it is employed in ſheathing the bottoms of ſhips, and in covering houſes—it is employed in ſtaining and colouring glaſs and enamels—the ſolution of copper in nitrous acid ſtains marble, and other ſtones: and, when precipitated with chalk, yields the green and blue verditer of the painters.——Copper is employed for chiſels, hammers, &c. in the gunpowder works, becauſe it does not ſtrike fire with flint.

CHAP. VI.

Of Iron.

IRON is an imperfect metal, of a blueiſh white colour, a nauſeous taſte, and when rubbed or heated a very diſagreeable ſmell, of a ſpecific gravity near 8 times that of water. It is hard and elaſtic, and lighter than any other metal, except tin. When it is in that ſtate which is called wrought or forged iron, it is very malleable, its tenacity is ſo great, that a wire one tenth of an inch in diameter can ſupport 450 pounds. Forged iron poſſeſſes one moſt valuable property, unknown in any other metal except platina, which is, that two pieces of it heated to a white heat can be united by the hammer. This property is called *Welding*.

Iron differs from all other metals in three particulars. 1ſt, In magnetiſm, or being attracted by the load-ſtone; and in becoming magnetical itſelf when rubbed to this ſtone. 2nd, In taking fire and fuſing by the ſtroke of a flint. If the ſparks be examined, they are found to be the calx of iron. 3rdly, In being found in plants and animals. Plants raiſed in water contain it; for it may be extracted from their aſhes.

Iron is the moſt abundant of all metallic ſubſtances, being found in moſt mineral bodies, coloured ſtones, &c. In its ores it is in three ſtates chiefly; in the metallic ſtate, though rarely; in the calcined ſtate; and mineralized with ſulphur and other ſubſtances. The calces are, the bog iron ore, generally diſpoſed in beds in the ſame manner as ſtones, and frequently containing ſhells, leaves, wood and other organic ſubſtances changed into iron. Of theſe ores there are ſeveral varieties; the magnetic ſtone, of a blackiſh colour, ſometimes called galena of iron, in cryſtals of 6 or 8 ſides: ſpecular iron ore, of a greyiſh colour, and ſometimes reflecting different colours; brown iron ore, as the blood ſtone; argillaceous iron ore, as the eagle ſtone, &c. &c. Iron mineralyzed with ſulphur is the common pyrites; with arſenic, the white pyrites or wolfram. The ſparry iron is combined with the chalky acid: it is for the moſt part of a whitiſh colour, always diſpoſed in thin layers, ſomewhat tranſparent like ſpar, and often in regular cryſtals. Iron is ſometimes combined with the ſulphuric acid forming the ſalt called martial or green vitriol. Plumbago is another ore of iron combined with charcoal; it is found frequently in England, and manufactured into black-lead pencils. Emery is alſo an ore in which iron is combined with ſiliceous earth: is is found in large quantities in the Eaſt Indies.

In the large iron works they generally roaſt the ores, as well for the purpoſe of expelling ſulphur or arſenic that may be in them, as to render them more apt to break into ſmall pieces convenient for melting: and ſometimes they pound them. The ſmelting furnaces are about 20 feet high: near the bottom is an opening for the pipe of a large bellows which is worked by ſteam or water; and in the ſides of the furnace are likewiſe ſeveral holes which are occaſionally opened to let out the ſlag or ſcum during the proceſs. The furnace is filled with charcoal, and lighted at the top. When it has burnt down a certain length, the ore is thrown in by ſmall quantities with ſome charcoal and limeſtone in ſtated proportions; the lime ſerving to aſſiſt as a flux, and alſo to dry the ſlag and ſeparate it from the melted metal. As the proceſs goes on the metal is ſeen falling in drops to the bottom, while the ſlag forms into a ſort of glaſſy matter floating on the top.

The melted iron, called *Font*, is let out at the bottom, generally three times; after each of which the hole is ſtopped with clay till next *Tapping*, or letting off the metal. It is run into moulds of whatever ſize and ſhape the artiſt thinks fit; and in this ſtate goes by the names of *Caſt Iron*, *Pig Iron*, or *Yetlin.* This crude iron is very impure, and may be diſtinguiſhed into three ſtates, 1ſt, White crude iron, ſo hard and brittle as to be in no degree malleable, and even to withſtand the file; 2ndly, Grey crude iron, leſs hard and brittle than the former; and uſed in the conſtruction of artillery and other inſtruments which are bored or turned; 3rdly, Black caſt iron, approaching ſtill more to the malleable ſtate. The ſlag removed during the operation ſometimes contains a ſufficient portion of iron to be employed again. A good furnace will yield from 3 to 4 tuns of iron in 24 hours.

Caſt iron is very valuable from its extenſive uſe in the various purpoſes of life: it is formed into great numbers of different utenſils, ſuch as ſtoves, ovens, pots, kettles, grates &c. &c., and is employed in every ſpecies of work large and ſmall, where iron does not require to be beat out with the hammer.

Caſt iron may be refined and rendered malleable by fuſing it with charcoal on which it is bedded in different layers. The fire muſt be blown pretty ſtrongly, and aſſiſted with fuſible matters. As the iron becomes ſoft, the artiſt ſtirs it continually with an iron inſtrument, as it were kneading and baking it, for the purpoſe of expoſing more of its ſurface to the combuſtible matters. In the courſe of ſeveral hours it acquires the conſiſtence of a paſte, and is then carried to a large hammer, which by repeated blows drives off the remaining portion of impure calx or ſlag. The charcoal is uſed to reduce the metal from its calcined ſtate, either by giving out phlogiſton to the calx, or according to the new theory by attracting its vital air. The iron, thus refined, becomes malleable, and is formed into bars: hence it is ſometimes called *Bar Iron*; it is alſo called *Forged Iron*, and *Wrought Iron*. Crude iron loſes above one fourth of its weight in refining.

It was obſerved above that forged iron poſſeſſes the property of welding; by which the great difficulty of fuſing iron, which cannot be accompliſhed without an intenſe heat, is in a great degree compenſated.

Another method of refining crude iron, leſs expenſive and troubleſome than the former, has been diſcovered; in which charcoal is not employed, and inſtead of the hammer, great rollers are uſed to force the impurities from the iron. If the calx of iron make but a ſmall part of theſe impurities, this method ſeems much preferable to the former but there being no proviſion here made for reducing the metal from the calx, the proceſs cannot ſucceed ſo well, if this be in great quantity.

Forged iron is made into *Steel* by cementing it with charcoal and other combuſtibles, and expoſing the whole to the heat of a reverberatory or vaulted furnace, in which the fire playing round them, keeps them in a white heat approaching to fuſion for 8 or 10 hours. When the required change takes place, which is indicated by the ſurface of the iron bars being bliſtered, the fire is allowed to decay, and the metal to cool. This is the common method; but ſteel is ſometimes made directly from crude iron, by running this into thin plates and cementing them with charcoal as before. The common method ſeems better, as having the advantage of one fuſion more beſide other proceſſes to purify the metal. It ſhould be obſerved, that during the operation of converting crude iron into ſteel, a black ſubſtance is thrown up to the ſurface, which is found the ſame with plumbago, an ore of iron before mentioned. It is evidently a combination of the calx of iron with charcoal from the proceſs. Steel may be farther refined for very nice inſtruments, as razors, lancets, watches, &c. &c. by melting it again with a ſtrong but regular fire in a crucible; it is then called *caſt ſteel*, although after this fuſion the bars of it are forged. This will not endure more than a red heat, but will run away like ſand from under the hammer, if urged to a welding heat.

Steel poſſeſſes qualities very ſuperior both to caſt and forged iron: It has great firmneſs of coheſion, yet it is malleable and may be welded like bar iron: It is leſs ſubject to ruſt than either of them: and it is capable of being brought to any degree of hardneſs or ſoftneſs, called the *tempering of ſteel;* which is thus done. The ſteel firſt receives the higheſt or hardeſt temper poſſible by ſuddenly plunging it red hot into cold water. It is then returned to the fire, and, as it ſlowly heats, a ſucceſſion of colours is obſerved, yellow, gold, purple, violet, deep blue; which determine the artiſt how long to continue and when to ſtop, according to the temper required. In the order here laid down, the firſt colours give the hardeſt, and the laſt the ſofteſt temper. It is obvious how uſeful this is: for in making different utenſils, for inſtance cutting inſtruments, if the temper be too hard, the edges will be apt to break, if too ſoft, to bend.

Iron undergoes the greateſt alteration of all metals from the air, and water; with the latter it combines ſo ſtrongly that not only its ſurface but the inner parts are corroded by it and changed to ruſt.

Iron is ſoluble in all the acids. The ſulphuric acid diluted with water diſſolves to the amount of more than half the weight of the acid: the ſolution being filtred and evaporated gives a tranſparent ſalt mentioned already under the name of martial or green vitriol. If to this ſolution be added ſome pounded nutgalls or other aſtringent vegetables, they combine with the calx, forming a fine precipitate which remains ſuſpended, eſpecially by the addition of a little gum: the fluid in this ſtate is ink.

The ſolution of iron in ſulphuric acid is alſo of importance in obtaining a very beautiful powder, called *Pruſſian blue*, which is of great uſe in painting and dyeing: it is done by adding to it a ſolution of alum in water, and throwing in a proper quantity of Pruſſian alkali, which will precipitate the iron partly in the form of a calx, partly in the form of Pruſſian blue: and by adding a little marine acid, the calx is diſſolved, and the powder thus rendered more pure. The *Pruſſian Alkali* is procured by calcining equal parts of fixed vegetable alkali with dried ox blood, throwing the maſs red hot into water, boiling and waſhing it well. This alkali is alſo of ſervice in reſtoring the characters of ancient writings that have faded; which may be done by an infuſion of nutgals, but it is beſt done by ſpreading a little diſſolved Pruſſian alkali over the characters.

Other ſubſtances, it is now known, beſide ox blood, are capable of giving the alkali the ſame property of precipitating iron in the form of Pruſſian blue, ſuch as the coals of burned animal ſubſtances, and alſo of vegetable ſubſtances, if they be treated with a more violent heat.

The ſolution of martial vitriol decompoſes nitre on two accounts; 1ſt, from the ſtronger affinity of ſulphuric than of nitrous acid to the alkali of nitre; and 2ndly from the attraction between the iron and this laſt acid, which is remarkably ſtrong in all caſes where iron is in very ſmall particles. In the combination of iron with nitrous acid a great quantity of nitrous gas is diſengaged, the metal is nearly calcined, and the ſolution is of a brown red colour.

The marine acid diſſolves iron with great rapidity, and diſengages more inflammable gas than even the ſulphuric: the ſolution of a yellowiſh green is more permanent than the ſolutions in the other acids. It is decompoſed by lime and the alkalis, by hepars and aſtringents: and by the Pruſſian alkali in a fine blue powder. Iron combines rapidly with ſulphur, merely with the aſſiſtance of moiſture; for a mixture of both in powder moiſtened into a kind of paſte will heat and ſplit and throw out flames, as we have obſerved in another place. In fuſion they readily combine, and form pyrites; and if iron heated to a white heat be paſſed through ſulphur, it is fuſed; which is much more eaſy than the common method of fuſing it.

Phoſphorus is ſometimes combined with iron, making the metal brittle, when it is cold, whence it is called *cold ſhort iron.* Zinc makes it brittle, when hot, whence this combination is called *hot ſhort iron.* Theſe imperfections are alſo frequently obſerved in iron after the proceſs of refining; and they ſeem to depend ſo much upon the ſtate of the ore, as not to be avoided by any management. Cold ſhort is accounted the worſe fault.

Iron unites with moſt metals: with mercury, if plunged in a white heat into it, the iron becomes coated; theſe two metals alſo intimately unite, when both in a calcined ſtate. It unites well with tin, as is evident from the manner of making tin plates mentioned in another place, and alſo from the tinning of iron veſſels, an operation ſimilar to that of tinning copper veſſels treated of elſewhere alſo. Antimony, which conſiſts of antimony properly ſo called and of ſulphur, being fuſed with iron is decompoſed by the greater affinity of the iron than of the metal antimony to ſulphur.

The uſes of iron are ſo various and extenſive, that it is impoſſible to enumerate them here. It is indeed the moſt uſeful of all metals, and is ſometimes called the ſoul of the arts. In medicine it is of ſervice, by ſtrengthening the nerves and muſcles, and in other reſpects. Martial vitriol, applied externally, is effectual in ſtopping violent bleedings; and iron, when it has become magnetical, being applied to the ſkin, relieves pains and allays convulſions.

CHAP. VII.

Of Lead.

LEAD is an imperfect metal, of a whitiſh colour inclining to blue—it is the leaſt ductile, elaſtic, and ſonorous of all metals—a wire of it, one tenth of an inch, is capable of ſupporting a weight of about thirty pounds—it is the heavieſt of all metals, except gold, platina and mercury; its ſpecific gravity being above eleven times that of water.

Lead is ſeldom found native, but for the moſt part in the form of a calx, either in an earthy ſtate, or of an ore united with ſulphur, and forming galena, or potter's red ore.—The ores of lead are of many different kinds; of which the following are moſt remarkable—firſt, ochre of lead, a kind of clay mixed with a ſmall quantity of ochre of iron—ſecondly, native ceruſe; which ſeems to be an ore of lead, reduced by water to a white earth—thirdly, ſparry lead; a calx ſlowly depoſited by water, and cryſtallized: it is of different colours, white, green, and ſometimes, though ſeldom, red—fourthly, galena; which is the true ore of lead, or the combination of this metal with ſulphur.—Moſt lead ores contain more or leſs ſilver.

The general method of ſmelting lead ore, now in uſe, is by the furnace called the cupola, or reverberating furnace; which is likewiſe uſed for the ſmelting of copper ores. This furnace is ſo conſtructed, as to melt the metal by the reflexion of the flame upon it. For this purpoſe, its roof is low and arched, and its chimney is placed oppoſite to the fire place, ſo that the blaſt of air may direct the flame from the fire towards the chimney, and in ſo doing cauſe it to ſtrike againſt the roof, whence it is driven back again upon the ore—the bottom of the furnace is made hollow, and ſhelving from the ſides towards the middle.

They generally put into this furnace about a ton of pounded ore, which they call a *charge*—three of theſe are worked off in twenty-four hours.—During the proceſs the ſmelters uſually throw in about a buſhel of lime, for the purpoſe chiefly of thickening and drying the ſcoria or ſlag, which floats upon the ſurface of the melted maſs, and which being liquid might otherwiſe flow out with the lead. When the ſlag is collected in this manner, towards the ſides, the lead is ſuffered to flow out of a hole at the bottom, which had been ſtopped during the ſmelting, and to run into an iron pot—it is then laded out of this into iron moulds, each of which contains a portion called *a pig of lead.*

lead.—Theſe pigs are ſold under the name of ore lead.

When the lead has all run out, they ſtop the hole, draw down the ſlag, renew the fire and the proceſs, and obtain from this ſlag to the amount of about twenty or thirty pounds.

Biſhop Watſon obſerving, that in this proceſs all the ſulphur is carried off in vapour, and much lead ſublimed, propoſes to have an horizontal chimney with various windings—upon its flue are placed a number of large globular glaſs veſſels, each containing a little water, and communicating together by means of two necks, one on either ſide. One of the extreme veſſels receives the vapour from a tube fixed at the end of the flue, which firſt riſes perpendicularly a little way, and then turns horizontally towards the glaſs veſſel: and thus the vapour is made to paſs through the whole ſeries, the neck of the other extreme veſſel being left open—the heat of the flue raiſes the water in the ſeries of veſſels into a kind of ſteam, which attracts and condenſes the ſulphureous vapour in its paſſage—when all the ſulphur is evaporated, the heat may be raiſed, and the draught of the furnace go out at the end of the horizontal chimney.—Ordinary ores contain at leaſt one-twelfth of their weight of ſulphur—a conſiderable ſaving of courſe is made, of ſulphuric acid, by this improvement.

The horizontal chimney is further uſeful, in ſaving a large quantity of ſublimed lead, eſpecially if it be conſtructed with various windings, to condenſe the vapour. The ſublimed lead is worth ten or twelve pounds a ton; and, perhaps, may be converted into red lead, with ſtill more profit.

When a maſs of metal, conſiſting of lead and ſilver, is melted in the open air, the lead will be reduced to aſhes, while the ſilver remains unaltered.—And thus lead, or any other, or all of the imperfect metals, may be eaſily ſeparated from ſilver or gold, which ſuffer no change from the fire: the imperfect metals, in the operation of fuſion, riſing to the top of the veſſel, in the form of an earth or droſs, while the gold or ſilver, or their mixture, falls pure to the bottom. This proceſs is greatly aſſiſted by adding to the maſs a quantity of lead, which by a ſtrong heat will vitrify, or be converted into glaſs, and which will ſoon vitrify all the imperfect ſubſtances, without having any effect upon the gold or ſilver—part of the vitrified ſubſtances is imbibed by the teſt or veſſel, which is for this purpoſe porous; the reſt is driven off from the ſurface of the melted maſs, by the blaſt of a bellows. The earth of lead thus driven off, is called litharge:—and it may either be changed into red lead by calcination, or revived into lead, by being fluxed with ſome combuſtible ſubſtance, as charcoal, &c.

Lead, during the progreſs of heat, melts with ſo ſmall a degree, that the hand may be dipped in it without injury—after it is melted, it begins to calcine—in a ſtrong heat it boils and ſends forth fumes, during which it calcines rapidly—if the heat be moderate and regular, its calx is a duſky powder, appearing as a pellicle on the ſurface, afterwards white, yellow, and then of a bright red, called *minium*, or *red lead.* If the heat be ſtrong and rapid, the lead becomes converted into *litharge:* and a ſtill higher degree of heat converts it into a clear, tranſparent, yellow *glaſs*, which is capable of diſſolving metallic calces, or earths, as was ſeen above.—This laſt calx of lead, added to common glaſs, renders it capable of being cut and poliſhed more eaſily: and, by its powerful action on the rays of light, is moſt proper for making the glaſſes of certain teleſcopes, called achromatic.—The glaſs ſo made, is called *flint glaſs*.

The calces of lead are alſo employed in making the finer glaſſes, called *paſtes*, which imitate the precious ſtones: the chief ingredients are flint, alkali, borax, and litharge.

Ceruſe, or *white lead*, is thus made—thin plates of lead are rolled up in a ſpiral form, and placed in earthen covered pots containing vinegar: this being gradually heated is raiſed into vapour, which corrodes the lead into white ſcales; and theſe are beat off from the plates, waſhed and ground in a mill.—The proceſs is again renewed with the plates, and continued till the whole are conſumed. White lead is employed in oil-painting, all other whites being tranſparent, unleſs laid on with water: it is alſo uſed to paint the ſkin, but is attended with certain ruin of the complexion.

White lead, litharge, or minium, if diſſolved in the acid of vinegar, becomes a ſweet ſubſtance, called *ſaccharum Saturni*, or *ſugar of lead;* which, like all preparations of lead, is a moſt deadly poiſon. Sour wines are ſometimes adulterated with this poiſon, which corrects the ſharpneſs, and communicates a flavour like that of native fermentation.--The beſt mode of detecting this is, by diſſolving ſulphur in lime water, and dropping a ſmall quantity of this ſolution into the ſuſpected liquor; for if any lead be preſent, a dark cloud will fall to the bottom, or the colour of the whole will be changed to a dark brown; if there be no lead, the colour will be rather a dirty white.

Lead, during its calcination, unites with air, as appears from its encreaſing in weight ten pounds in the hundred—and it is confirmed by Dr. Prieſtly, who extracted pure air from minium.—Yet it is one of the metallic ſubſtances, which has the leaſt affinity with air, for this ſeparates from it by the action of fire alone. We are not to judge of the degree of affinity between two bodies, by the facility with which they combine, but rather by the difficulty of diſuniting them.

Lead is tarniſhed by air, eſpecially if this be moiſt; and is corroded by water, particularly by that which contains ſaline matters, as appears from the white cruſt covering the ſides of the veſſels. It unites with earthy ſubſtances, but only when in the ſtate of a calx. It is ſoluble in all the acids, though ſlightly in its metallic ſtate; in the ſulphuric, when concentrated and boiling, compoſing vitriol of lead:—in the nitrous acid, in its ordinary ſtate (probably from the ſtrong attraction of lead to vital air) compoſing the ſalt called nitrum Saturni, which crackles on the fire, and fuſes upon a burning coal with a yellowiſh flame. But, although the nitrous acid ſeems to act much more ſtrongly upon lead, than the ſulphuric, yet its affinity is leſs; as is evident from pouring ſome pure ſulphuric acid into a nitrous ſolution of lead, by which vitriol of lead is precipitated, in the form of a powder uſed in painting, and called *white precipitate.*—The pure marine acid, with the aſſiſtance of heat, readily calcines lead, and diſſolves part of its calx: but it combines better with it, by pouring the marine acid into a nitrous ſolution of lead: by which a more copious precipitate is formed, than was made by the ſulphuric acid.—It is called *plumbum corneum.* Sulphur eaſily unites with lead by fuſion, and produces a brittle mineral, like galena, much more difficult to fuſe than lead.—It is curious to obſerve, that ſuch metals, as are very fuſible, become much leſs ſo when fuſed with ſulphur; and that thoſe, which fuſe with difficulty, are rendered much more fuſible by this combination.

Lead is acted on by all inflammable ſubſtances. Groſs oils diſſolve its calces by the aſſiſtance of heat: and theſe preparations are employed in many plaſters which are uſed in ſurgery. Lead unites with moſt metals and ſemi-metals—gold and ſilver are diſſolved by it in a ſlight red heat:—the lead becomes more ductile, while they become more brittle.—Mercury forms with it an amalgam: but the lead is eaſily ſeparated from it by agitation, in the form of a fine powder.—Lead, when heated ſo as to boil and ſmoke, ſoon diſſolves copper thrown into it: but the union is remarkably ſlight; for by a very moderate heat, the lead almoſt entirely runs off by itſelf. This proceſs is called eliquation, and is the only inſtance of ſeparating metals in this manner hitherto known; as in all other caſes, the compound fuſes into one maſs.—Lead does not unite with iron in their metallic forms, but vitrifies it, and all other imperfect metals, in the ſtate of calces, as was ſhewn above.—It unites very readily with tin, forms a compound more fuſible than lead, and is, therefore, uſed as a ſolder for it—the proportion of the ingredients is, one part of tin for two of lead, to make ſolder for plumbers.

It is very dangerous to employ tin, which is combined with too great a quantity of lead, in veſſels of domeſtic uſe.—Ten pounds of lead in the hundred, is the proportion in fine wrought tin; whereas five and twenty pounds of lead are often found in a hundred weight of common tin. There is an eaſy method of trial uſed by pewterers, called the eſſay by the ball or medal—the tin is run into moulds of thoſe ſhapes, and is compared in weight with refined tin run into the ſame moulds.

The uſes of lead are numerous. Beſide thoſe already mentioned, it is caſt into thin ſheets for covering buildings, employed in making water pipes, and various other inſtruments and utenſils. If melted lead be poured into a box, previouſly rubbed with chalk, to prevent it's action on the wood, and be continually ſhaken, it will form into ſeparate grains, which are of conſiderable uſe, eſpecially in weighing.—*Shot* is made, by pouring melted lead into an iron box, bored with ſmall holes in the bottom, through which it runs into a veſſel of water—as it touches the ſurface of the water, it congeals and forms itſelf into round drops—a ſmall quantity of arſenic being added to the water, gives more ſucceſs to the experiment.

In preparations of lead, the workmen are ſubject to complaints in the bowels, and to paralytic diſorders—when received into the ſtomach and bowels, it occaſions violent pains, accompanied frequently with vomitings of green bile. In theſe caſes antimonial emetics and purgatives are found of great ſervice, and alſo livers of ſulphur. From theſe facts it ſhould ſeem, that lead ought not to be uſed internally, by way of medicine; and even externally with great caution.

CHAP. VIII.

Of Tin.

TIN is an imperfect metal of a whitiſh colour, more brilliant than lead, but leſs ſo than ſilver. It is the lighteſt of all metals having a ſpecific gravity little above 7 times that of water, ſofter than any of them except lead, and inconſiderably ſonorous. A tin wire one tenth of an inch is able to ſupport a weight of about 50 pounds. It is very malleable, and is beaten out into leaves of different thickneſs according to their various uſes; ſome of them are not above the thouſandth part of an inch in thickneſs, called tin foil. It is of all metals the moſt fuſible.

Tin is very ſcarcely, if ever, found in a native ſtate: but generally in the ſtate of a white, heavy, opake calx. Its ores are as follow: 1ſt, tin ſpar of a whitiſh grey colour, ſometimes inclining to green and yellow; 2nd, dark brown or black, bedded in quartz: theſe ores contain ſome iron; 3rd, red or garnet ore, containing more iron than tin; 4th, the tin ſtone, which contains ſtill leſs tin than the former.

Tin ores are worked thus. The ore is pounded into powder; waſhed to carry off the earthy particles; and roaſted to ſeparate the ſulphur and arſenic when found in thoſe ores. This is done in reverberating furnaces with an horizontal chimney to collect the ſulphur. The powder is then thrown into the ſmelting furnace, fuſed and run into moulds. In England theſe moulds are of ſtone, of a quadrangular ſhape, containing about 320 pounds weight of metal, which when hardened is called *Block Tin*: each of them is ſealed with the ſeal of the Dutchy of Cornwall, where the mines are worked.

Engliſh tin is ſaid by foreigners to be very impure, but this is a miſtake. The tin of which they complain, does not leave England in that ſtate, but is adulterated afterwards. The Dutch for inſtance melt thoſe blocks again with lead, and after thus debaſing the tin, ſtamp it with falſe Engliſh ſtamps. It ſhould here be obſerved, that no tin, except native can be perfectly pure; becauſe its calx being very refractory, the fire, which ſmelts it, is ſtrong enough at the ſame time to fuſe the copper, iron, and other metals mixed in the ore. If tin be melted in open veſſels its ſurface is ſoon covered over with a grey pellicle, which being taken off, the tin beneath is covered with a new one; and ſo on, till the whole is thus reduced into pellicles, which are the calx of the metal.

This calx being pounded well and agitated in water, is ſuffered to ſtand a conſiderable time and afterwards decanted; when it lets fall a very fine powder, which is called putty of tin. It is of great uſe in poliſhing metals, and the glaſſes of teleſcopes. This is a different ſubſtance from glazier's putty, which is made of whiting powdered with a ſmall quantity of white lead, and ſo much oil as to make a ſtiff paſte.

The brightneſs of tin, when ſcraped, ſoon goes off by expoſure to the air: but it is not ſubject to ruſt.

The concentrated ſulphuric acid unites with tin, eſpecially with aſſiſtance of heat, and diſſolves about half its weight of tin, at the ſame time diſengaging a ſtrong ſulphureous gas. The tin falls down in the form of a white calx. In this ſolution ſulphur is formed, which renders the fluid of a brown colour while it remains heated, but which ſubſides when it cools. Nitrous acid combines with tin moſt rapidly, even in the cold. This is probably owing to the ſtrong tendency which tin has to pure air, and to the ſlighter attraction which this air has to the nitrous gas. Moſt of the metal falls down in the form of a white calx: and red nitrous gas is rapidly diſengaged. This calx is reckoned the moſt proper baſis for all fine colours, yet diſcovered. It is perfectly white, capable of being reduced to an extreme degree of fineneſs; and is unalterable by alkalies, acids, or the ſun and weather, and even by the heat of a burning mirror. But it will not mix with ſugar of lead, cream of tartar calcareous earths and ſome other ſubſtances uſed in colour making. Marine acid unites with tin, and takes up more than half its weight. The acid loſes its colour and property of fuming. A ſlight effervefcence takes place, and diſengages a fetid inflammable gas. In this ſolution there is no precipitate of the metal as in the former caſes: but by evaporatien cryſtals are formed in brilliant and regular needles; this ſalt called ſalt of tin, is ſometimes uſed in manufactures of printed cloths. The fuming liquor of Libavius is but a ſolution of tin in marine acid, prepared after a particular manner.

Tin is diſſolved in aqua regia, conſiſting of two parts of nitrous, and one of marine acid, and much heat produced. In order to obtain a durable ſolution, the metal is to be added by degrees, otherwiſe part of it will be calcined. In this manner aqua regia will diſſolve half its weight of tin., The ſolution has the appearance of a browniſh jelly. It is uſed by dyers to heighten the colours of cochineal, gum lac, and other red tinctures from crimſon to a bright ſcarlet, in the dyeing of woollens.

Pure tin is diſſolved by common and by diſtilled vinegar in conſiderable quantity, even although the vinegar be diluted with water: according to M. Macquer. The detonation of this metal with nitre is very rapid: to do this, it is fuſed in a crucible, and upon it is thrown ſome very dry nitre in powder. A white and brilliant flame is produced. When by a farther addition no detonation takes place, the tin is entirely calcined.

Tin eaſily combines with ſulphur, by throwing about a fourth part of powdered ſulphur upon the tin in fuſion. A brittle maſs is formed, diſpoſed in flat needles united in bundles. This metal may be combined much more largely with ſulphur, by amalgamating the tin with half its weight of mercury, and by mixing with this amalgam when cold half its weight of ſal-ammoniac and half its weight of ſulphur. All theſe ingredients are well rubbed together and put into a retort. If the heat be moderate, and not contined too long, gold coloured flakes are produced by the combination of tin and ſulphur. One hundred parts of tin contain about forty of ſulphur. The compoſition is called aurum muſivum, and is employed by artiſts to bronze ſtatues.

Tin unites more or leſs with the metals: with mercury it readily forms an amalgam: with arſenic if combined with vegetable alkali, it forms a brittle a brittle compound of a plated texture. It is thought that all tin contains ſome arſenic which makes it dangerous in kitchen utenſils. But the quantity is ſo exceedingly ſmall that little is to be apprehended from the uſe of tin on this ſcore, amounting in pure tin only to one grain in a French ounce, or little more than the ſix hundreth part of the whole. Zinc unites with tin very well, making it harder and more brittle: and is one of the principal ingredients with tin in the compoſition of pewter. The beſt pewter contains ſixteen parts in twenty of tin: the remainder conſiſt of the metallic part of antimony zinc, copper, biſmuth, and ſuch other ſubſtances as improve the hardneſs and colour. But inferior ſorts of pewter contain a good deal of lead: and are of courſe unſafe for domeſtic purpoſes.

The uſes of tin are very numerous. Several of theſe have been already mentioned. Among others the ſilvering of looking glaſſes, as will be ſhewn in the next Chapter. Alſo the tinning of iron and copper veſſels, which is done in the following manner.

Copper may be tinned, by covering the copper with a plate of tin hammered upon it. But the common method of tinning conſiſts in making the ſurface of the copper veſſel within quite bright, ſcraping it, and waſhing it with diſſolved ſal ammoniac. It is then heated, and melted tin poured into it; which being made to flow into every part of the veſſel, unites when cold with the copper. Reſin or pitch are ſometimes uſed, to prevent the tin from being calcined, and the copper from being ſcaled.

In this proceſs, a grain of tin is ſpread over three or four ſquare inches. This covering is very thin. A new method is ſaid to have been invented at Paris, by which twenty times this quantity may be laid on. Till this compoſition is better known, tin ought to be laid on in the former method as thick as poſſible. The veſſels ought alſo to be kept conſtantly clean: for the corroſion of tin by vinegar, juice of lemons, and other acids is very ſlight and imperceptible, unleſs they are ſuffered to lye ſome time upon; it and even copper itſelf, with ſuch care, might be ſafely uſed, eſpecially for animal food.

Iron is tinned after the following manner. Plates of iron are rolled to a proper thickneſs. They are then ſteeped in a weak acid liquor, which cleans their ſurfaces from ruſt; for ruſt is the earth of iron, and no metal will combine with an earth. Let the plates then be ſcoured quite bright, and placed in a pot filled with melted tin, whoſe ſurface is covered with ſuet or pitch, to prevent the tin from being calcined. The tin will ſoon cover each ſide of the plates with a thin white coat. They are then what are called tin-plates. In the ſame way ſtirrups, buckles and bridle bits are covered with coats of tin. The advantage of this is, that iron is apt to ruſt, but tin is not.

CHAP. IX.

Of Mercury.

MERCURY, which is alſo called QUICKSILVER, is a metal of a blueiſh white colour, heavier than any other of the metals, except gold and platina; its ſpecific gravity being 13½ times that of water. It differs from all other metallic ſubſtances, in being conſtantly in a fluid ſtate, unleſs in very cold climates, or congealed by artificial cold: in which caſes it becomes ſolid, and ſo hard as to bear the hammer. This was obſerved by M. Pallas in Siberia.

Mercury is not found in great abundance in nature. Some minerals probably contain a portion of it undiſcovered, becauſe in working them, the mercury, which is very volatile, flies off in vapour.

Mercury is either native, or mineralized with other ſubſtances, eſpecially ſulphur. Native mercury is ſometimes, though ſeldom found in its running ſtate, and conſiderably pure. In combination with ſulphur it is called *cinnabar*, a red mineral ſubſtance, ſometimes intermixed with earths and ſtones, or interſperſed through the ores of other metals, ſilver, copper, iron-pyrites, &c. In general an hundred parts of cinnabar contain about eighty of mercury, twenty of ſulphur. The mines of Idria in the Auſtrian dominions, Almaden in Spain, and Guancavelica in Peru, are the principal quickſilver mines. Native mercury is eaſily obtained by waſhing, to ſeparate it from the earthy and other ſubſtances with which it may be mixed. But cinnabar muſt be diſtilled, to ſeparate the ſulphur; for the moſt part in conjunction with lime, which lays hold on the ſulphur, and prevents its being volatilized with the mercury. If the cinnabar ore ſhould contain calcareous earth, the addition of lime is unneceſſary. The finer kinds of cinnabar, being more valuable than mercury, are not wrought to obtain it; but are either uſed in medicine, or as a fine paint called *vermillion.* The paint of this name which is commonly employed, is not native, but an artificial compound of mercury and melted ſulphur. There is alſo another compoſition of mercury and ſulphur, equal parts of each in a fluid ſtate, which being triturated together, form a black powder, called *Ethiop's mineral.*

Although mercury is not altered by expoſure to air, yet by a rapid and continual motion it is changed to a fine black powder called *Ethiop's* *per ſe.*—This powder, if heated, gives out vital air, and the metal is revived.

If mercury be expoſed to ſuch a heat, in open veſſels, as to make it riſe in vapour, it becomes converted into a red calx, called *precipitate per ſe*: in cloſe veſſels it boils like liquids.—The vapour, when confined, produces great exploſions.

Mercury combines with ſulphuric acid, when concentrated and boiling. If one part of the former, with about two of the latter, be heated in a retort, the ſurface of the mercury becomes white, and a powder of the ſame colour is ſeparated from it, ſulphureous gas being diſengaged in abundance—when this ceaſes to come over, the reſidue appears to be a white maſs, the greateſt part of which is the calx of mercury, the reſt a ſalt called vitriol of mercury. If this ſalt be diſſolved in boiling water, the undiſſolved calx aſſumes a bright lemon colour, and is called *turbith mineral*: it is uſed in medicine, and is alſo capable of making a fine paint. The ſalt alſo depoſits the ſame powder, by adding a large quantity of hot water.—The fixed alkalies, lime and magneſia, decompoſe mercurial vitriol, precipitating the mercury from its ſolution.

Mercury is diſſolved by nitrous acid, even in the cold; the colour of the acid becoming green during the eſcape of the nitrous gas. A calx is precipitated, like the former, by the addition of hot water, and is called *nitrous turbith*—the ſolution is cauſtic, and forms a black ſpot upon the ſkin.—When all the mercury that can be diſſolved by heat is taken up, it aſſumes the appearance of a ſaline ſubſtance, and has the name of *mercurial nitre*—if this be expoſed to a long continued heat, it becomes a powder called *red precipitate*, having the ſame properties with precipitate per ſe.—Nitrous ſolution of mercury is a good teſt of mineral waters, which may contain any of the alkalies, lime, magneſia, barytes, ſulphuric acid, or any ſalts of which this acid makes part; for all theſe precipitate the mercury in different calces, white, yellow, dark grey, &c.

The marine acid does not act upon mercury, in its metallic ſtate, although it has a ſtronger affinity to it in the ſtate of a calx, than the other acids; as is evident from its power of decompoſing the ſolutions of it in either—in this caſe it attracts the mercury, and precipitates it in the form of a powder, called *white precipitate*.—If the acid and calx meet in the form of a vapour, they form *corroſive ſublimate*: which may be made in ſeveral ways, and among theſe the following—let equal quantities of calx of mercury, common ſalt, and martial vitriol, be expoſed to a moderate heat: the ſulphuric acid decompoſes the common ſalt, ſetting free the marine acid, which riſes in vapour with the calx, to the top of the veſſel, and forms the ſublimate. If with this be triturated fluid mercury, added by little at a time, until no more can be abſorbed, the compoſition is what is called *calomel*, or ſweet mercury. A little water ſhould be uſed in this proceſs, to prevent the noxious duſt of the ſublimate from riſing.

There is another important preparation of mercury with antimony. Two parts of corroſive ſublimate are mixed with one of crude antimony (which conſiſts of ſulphur united to the metal) and are diſtilled together: the marine acid quitting the ſublimate will lay hold on the regulus or metallic part of antimony and riſe in a compound called *Butter of Antimony*, while the ſulphur uniting with the mercury forms Cinnabar. By a ſimilar proceſs may be made *Butter of Arſenic*, *Butter of Biſmuth*, &c. When butter of antimony is thrown into diſtilled water, the calx of antimony precipitates in *Emetic powder*, or *Powder of Algaroth*, from the name of a phyſician, who employed it as a medicine: it is a ſtrong purgative as well as emetic. Mercury combines with oils by trituration, and forms with them various ointments of a black or deep blue, much uſed in ſurgery.

It unites well with moſt metals, particularly with gold and ſilver, as was ſhewn in another place. In working the mines of theſe precious metals its uſe is indiſpenſable, and great quantities of it are conſumed in this way. Its combinations with the metals are called Amalgams, of which ſome inſtances have been given below. An amalgam with tin is uſeful in ſilvering looking-glaſſes, which is done thus: tin foil is ſpread ſmoothly upon a flat table, and ſome mercury being poured on, is gently rubbed, and ſpread uniformly over the ſurface. A plate of glaſs is then cautiouſly ſlid upon this coat in ſuch a manner, as to ſweep off any redundant mercury, and weights are laid upon the plate for ſome time; by means of which the amalgam adheres firmly to the glaſs, even after their removal. About two ounces of mercury cover three ſquare feet of glaſs.

Mercury is reckoned pure, if it be perfectly fluid, if it forms into ſmall round globules, if it is without ſcum on its ſurface, and if it does not ſoil the fingers in handling. The uſes of mercury are numerous; ſeveral of which have been already mentioned, ſuch as the working of gold and ſilver mines; forming various amalgams for gilding, ſilvering, &c.; conſtructing thermometers and barometers; and in medicine, where its application is moſt powerful and extenſive, but ſhould be admitted with great caution and ſkill.

CHAP. X.

Of Zinc.

ZINC is a ſemi-metal of a blueiſh white colour like lead, though ſomewhat brighter, of a ſpecifick gravity, little above 7 times that of water. It is hard, ſonorous, and in a ſlight degree malleable: it cannot eaſily be reduced to ſmall grains, unleſs by pouring it when fuſed into cold water, nor into a powder unleſs nearly melted. It melts with a moderate heat, and is the moſt volatile of all metallic ſubſtances except arſenic. When melted in contact with air, it becomes covered with a grey pellicle; and when urged with a ſtronger heat, it burns with a green or yellowiſh blue flame, and at the ſame time light white flakes called flowers of zinc, are ſublimed: both the grey and white powders are calces of zinc but in the latter caſe the metal is more calcined than in the former. The calx of zinc is not volatile, but by a very ſtrong heat may be converted into a clear yellow glaſs.

Zinc is very ſeldom found native; but for the moſt part in the ſtate of a calx. Its principal ore in this ſtate is Lapis Calaminaris or *Calamine*, of different forms and colours; containing iron, clay, calcareous and other earths, and lead. Another ore of it is *Blende*, called alſo mock-lead or black jack, conſiſting of zinc mineralized with ſulphur. This is often miſtaken by inexperienced ſmelters for lead ore. So calamine in its appearance can ſometimes hardly be diſtinguiſhed from limeſtone, but it is twice as heavy. Zinc is alſo found mineralized with ſulphuric acid: this ore is called *White Vitriol* or *Vitriol of Zinc*. Calamine ores are treated, by roaſting for the purpoſe of driving off any ſulphureous or other volatile matters; then by carefully picking out all foreign ſubſtances; then grinding to a fine powder, and waſhing this is in water to carry off the light earthy particles. In this condition it is fit for the braſs-makers.

The manner of making braſs with calamine has been already ſhewn under the head of copper: but a further improvement is made, by mixing calamile and charcoal with moiſtened clay, ramming this mixture to the bottom of the melting pot, and placing the copper along with charcoal upon the clay. When the fire is applied, the vapour of the reduced calamine, or zinc, makes its way through the clay to the copper, while the iron or lead contained in the calamine, not being ſo volatile, remain behind. By this proceſs the braſs is conſiderably pure.

Black jack is not ſo commonly uſed for making braſs as calamine: yet it is thought by ſome very well adapted to this purpoſe, with proper management.

Beſide braſs, a combination of zinc and copper makes tombac or pinchbeck, which imitates the colour of gold, but is not ſo malleable as braſs. Different proportions of the two metals in this mixture are aſſigned: but that moſt generally admitted is three parts of zinc to four of copper.

Zinc is obtained from its ore of calamine in the following manner. Pots are placed in a circular oven, through the bottoms of which, and alſo the floor of the oven, iron tubes are made to paſs into a veſſel of water: the pots are filled with calamine and charcoal, and the mouth of each ſtopped cloſe with clay; when the fire is applied, the metallic vapour of the reduced calamine, or zinc, iſſues through the tube and is condenſed in ſmall particles in the water. Theſe are afterwards melted, and formed into ingots, and ſold under the names of zinc or ſpelter: but the ſubſtance ſometimes ſold under the latter name is a kind of ſoft braſs in the form of grains, which is uſed by braziers and others for ſoldering.

If zinc, after it has been obtained from its ores, ſhould, as is often the caſe, contain lead, iron or other metals, it may be purified by melting it with ſulphur and ſome fat ſubſtance to prevent its calcination: the ſulphur will lay hold on the other metals, forming with them a ſort of ſcoria or ſcum on the ſurface which muſt be taken off.

Zinc unites with moſt metals: its union with tin makes a conſiderable part in the compoſition of pewter, as was obſerved before.

Zinc is diſſolved by ſulphuric acid diluted with water, much inflammable air being at the ſame time diſengaged, and the temperature of the acid encreaſed. But as the combination goes on, the temperature diminiſhes, and the ſalt begins in conſequence to form in four ſided cryſtals. This ſalt is called vitriol of zinc, being the ſame with the ore of that name. The ſame ſalt may alſo be procured from ſuch ores of zinc as are mineralized with ſulphur, by roaſting the ore ſo as to burn the ſulphur; for ſulphuric acid will be thus obtained, which diſſolves the calx of zinc, and by waſhing off the ſalt from the ore, and by evaporation, it forms into chryſtals. The nitrous and marine acids alſo act upon zinc ſtrongly: the former ſolution is very cauſtic, and affords cryſtals which ſlightly detonate: the latter does not cryſtallize.

The uſes of this ſemi-metal are chiefly for making braſs and other mixtures. It is ſuggeſted that it may be employed to advantage in lining copper veſſels in the place of tin; but this matter has not been yet ſufficiently aſcertained. Its calces are ſometimes employed in fire-works: and both theſe and its ſalts in medicine.

It ſhould be obſerved that zinc is ſometimes obtained from what is called *Cadmia Fornacum*, or the Cadmia of the Furnaces; which is a ſublimate of zinc that adheres to the walls and chimneys of furnaces during the ſmelting of lead, iron or other ores, in which a portion of zinc is contained.

CHAP. XI.

Of Antimony.

ANTIMONY is a ſemi-metal of a whitiſh colour like tin or ſilver near five times as heavy as water: very brittle, and of a plated or ſcaly texture. In a ſtrong fire it is volatile, and volatilizes part of other metals, except gold and platina. With a moderate heat it is calcined into a light grey calx: and by continuing and raiſing the heat, it ſublimes in white fumes, which may afterwards be fuſed into glaſs: they are called *argentine flowers of regulus of antimony.*

Antimony is ſometimes found native, but for the moſt part mineralized with ſulphur. It muſt be carefully obſerved that this ore is generally though improperly called antimony, and the ſemi-metal itſelf is called regulus. The ore is of a dark grey, ſometimes mixed with lead and iron. Regulus of antimony is obtained by heating the pounded ore till it melts: the ſulphur and other volatile matters fly off, and the regulus becomes calcined. In this proceſs ſome part of the ſulphur remains combined with the calx; and when this calx fuſes into a glaſs, it is more or leſs tranſparent according to the diſſipation of the ſulphur as well as the degree of calcination. If much ſulphur be remaining, the glaſs is of a dark red colour; whence it is called *Liver of Antimony.* The ſulphur is beſt ſeparated by acids, particularly the nitrous acid and aqua regia; which diſſolve the regulus, and leave the ſulphur.

The calx of antimony may be reduced to the regulus by heating with it in a crucible an equal weight of black flux with a little black ſoap: the alkali contained in theſe matters unites with the ſulphur in the calx, while the charcoal aſſiſts the reduction of the metal: thus at once reviving and purifying the regulus. This proceſs ſucceeds beſt in cloſe veſſels.

Regulus of antimony is partly diſſolved by concentrated ſulphuric acid boiled ſlowly upon it, but the greateſt part is reduced to an inſoluble calx. The former gives the ſalt called *Vitriol of Regulus*, which does not cryſtallize. In this proceſs much ſulphureous gas eſcapes, and ſome ſulphur is ſublimed.

Nitrous acid acts ſtrongly upon regulus of antimony even in the cold, diſſolving a portion and calcining the greateſt part. The ſalt in this caſe is the *Nitre of Regulus.* The marine acid does not act well upon it in the liquid ſtate, but muſt for this purpoſe be combined with ſome metallic baſis, as for inſtance combined with mercury in the form of corroſive ſublimate. If this ſublimate be diſtilled with the regulus, the marine acid will leave the mercury, and will unite with the regulus, coming over together, and forming butter of antimony, as was ſhewn in another place. Aqua regia diſſolves the regulus better than either of the ſimple acids which compoſe it: it ſeems to be the proper medium between the rapid action of the nitrous acid which calcines too faſt, and the too ſlow operation of the marine acid.

Regulus of antimony decompoſes ſeveral neutral ſalts, of which nitre deſerves moſt notice. If equal parts of regulus and nitre, or three parts of nitre with one of crude antimony be thrown into a red hot crucible, a detonation takes place, and the reſidue conſiſting of vegetable alkali and calx of antimony is known by the name of *diaphoretic antimony* a powerful medicine.

There are ſeveral other preparations of antimony, of which the two following are chiefly in uſe, antimonial wine and emetic tartar.

Antimonial Wine is prepared by infuſing powdered glaſs of antimony in white wine: a ſmall quantity is taken up, more or leſs as the wine is more or leſs acid. The infuſion is to ſtand for ſome days; after which the fluid muſt be carefully decanted and filtred through paper.

Emetic Tartar is prepared by throwing equal quantities of crude antimony and nitre into a crucible heated to a white heat. The melted mixture is then poured out, and being carefully ſkimmed is, when cold, reduced to a very fine powder, which is repeatedly waſhed and boiled in water, till it becomes inſipid. Equal quantities of this powder, and of the cryſtals of cream of tartar are boiled together in water for half an hour, allowing three pints of water to each pound of mixture. The liquor is then filtred evaporated and cryſtallized: and the ſalt reſulting is the emetic or antimoniated tartar, and is thought to be one of the ſafeſt preparations of antimony.

This ſemi-metal combines with moſt other metallic ſubſtances: its combinations have been ſhewn in ſome of the moſt important inſtances. The uſes of antimony are numerous; it is employed in metallic ſpecula to give the compoſition a finer texture: it is uſed in the compoſition of printing types, bell metal, pewter, ſmall ſhot &c. it aſſiſts in the caſting of cannon, and is employed in purifying gold: its application in medicine is alſo extenſive.

CHAP. XII.

Of Biſmuth.

BISMUTH is a ſemi-metal, of a yellowiſh white colour, very heavy, having near nine times the weight of water, and ſcarcely, if at all malleable, being eaſily broken, and even reduced to powder by the hammer. With a moderate heat it melts, and its ſurface becomes covered with a greeniſh, grey, or brown calx. A ſtronger heat cauſes it to burn with a ſmall blue flame; at the ſame time that a yellowiſh calx is driven up by the force of cumbuſtion, known by the name of Flowers of Biſmuth. This calx is not volatile, but, when expoſed alone to the action of fire, is fuſed into a greeniſh glaſs. In cloſe veſſels, this ſemi-metal entirely ſublimes. Biſmuth is often found in a metallic form in nature: this is known by its colour, by its ſoftneſs, which is ſuch, that it may be cut with a knife, and by its fuſibility. It is found too, mineralized with arſenic or ſulphur. Biſmuth is alſo found in the form of a calx, a powder of a greeniſh yellow.

Biſmuth is eaſily ſeparated from its ores by fuſing the ore upon wood, and letting the melted metal fall through the wood into a hole made in the ground.

Biſmuth is a little tarniſhed by the air, but is not attacked by water.

Sulphuric acid, concentrated and boiling, acts in ſome degree upon biſmuth, giving partly a white calx, and partly a ſalt called Vitriol of Biſmuth. The nitrous acid diſſolves biſmuth with great rapidity. If to this ſolution we add water, the calx of biſmuth falls to the bottom, in the form of a white powder called *white paint*, or *magiſtery of biſmuth:* with a good deal of water this is very white and fine. It is uſed to whiten the ſkin, but blackens it when near to odorous or cumbuſtible bodies. The uſe of any paint probably injures the ſkin; and, from the reſemblance of this ſemi-metal to lead, there is reaſon to ſuſpect that its calx is attended with ſimilar noxious effects to thoſe occaſioned by the calx of lead. The marine acid does not act ſtrongly upon biſmuth, unleſs when concentrated, and diſtilled in a large quantity upon it. The ſalt reſulting is of a ſoft kind, and is called Butter of Biſmuth.

This ſemi-metal unites with moſt metallic ſubſtances, and renders them in general more fuſible. Glaſs of biſmuth, eſpecially when combined with copper, poſſeſſes very ſtrong diſſolving powers, and may be uſed with advantage in the cupellation or proceſs of refining the perfect metals.

Biſmuth is alſo extremely uſeful in forming ſolders, on account of its flowing thinner and more eaſily than any of the metallic ſubſtances, and of its communicating theſe properties to all the other metals with which it is united: ſo that the work to be ſoldered ſuffers no damage from the moderate heat required to melt the ſolder, while the thinneſs of the melted matter inſinuates into the ſmalleſt crevices of the ſides to be joined. Biſmuth, for the ſame reaſon, is of great ſervice in the compoſition of printing types; cauſing theſe to take off the greateſt ſharpneſs and preciſion from the moulds in which they are caſt. And theſe impreſſions are rendered ſtill more accurate by another property of this ſemi-metal, which is, that, while it cools, it encreaſes in bulk; which no other metallic ſubſtance, except iron, is known to do.

Such are the important uſes of this ſemi-metal: to which we may add, that it is employed in the compoſition of pewter, and other metallic mixtures; and alſo, that when it is reduced to a powder, and applied with the whites of eggs to wood, it gives it the appearance of being ſilvered.

CHAP. XIII.

Of Arſenic.

ARSENIC, ſometimes called Regulus of Arſenic, is a ſemi-metal, of a yellowiſh white colour, having a ſpecific gravity more than 5½ times that of water, ſubject to tarniſh by expoſure to the air: when very pure, the colour is a blueiſh white. It ſublimes with heat in cloſe veſſels, but in the open air burns with a ſlight flame, and is the moſt volatile of all metallic ſubſtances. Its fumes have a ſtrong ſmell of garlic, particularly when burnt with charcoal.

Arſenic is often found native, having the metallic luſtre, and compoſed of ſmall ſcales; or in black maſſes, not brilliant, but very heavy; in this laſt ſtate it is diſtinguiſhed by its weight. Sometimes it is found in the ſtate of a white calx, in the form of flowers, and mixed with ſome earths. Again, it is often united with ſulphur, compoſing what are called *orpiment*, a bright yellow, and *realgar*, a ſcarlet red: theſe two ſubſtances

ſtances differ in the proportions of their ingredients; the former containing four parts of ſulphur to one of arſenic; the latter four of arſenic to one of ſulphur. Orpiment is changed to realgar by a greater degree of heat; probably becauſe a large quantity of ſulphur is driven off. Another mineral of arſenic is Miſpikel, or arſenical pyrites, where the ſemi-metal is found combined with iron; it is alſo ſometimes united with cobalt, antimony, tin, copper, and ſilver.

The arſenic met with in commerce is the white calx before mentioned: it is chiefly brought from the cobalt works in Saxony, where it is driven off by long roaſting in furnaces with horizontal chimneys, and condenſed into a grey powder. This is refined by a ſecond ſublimation in cloſe veſſels, with a little potaſh to detain the impurities. It has a very ſtrong and cauſtic taſte, and is a violent poiſon. The ſymptoms attending this are, a dryneſs of the mouth, roughneſs of the throat, pains in the ſtomach and bowels, vomitings, cold ſweats, convulſions, &c. As antidotes to this poiſon, mucilaginous drinks, milk, ſweet oils, whites of eggs, and ſuch like are adminiſtered. Calcareous liver of ſulphur, containing a little iron, is alſo recommended; and, when the firſt ſymptoms are over, the uſe of ſulphureous mineral waters.

If the calx of arſenic be mixed with black ſoap into the conſiſtence of a paſte, and expoſed at firſt to a gentle heat, which muſt afterwards be encreaſed,

creaſed, the metal is revived in the form of a ſublimate at the top of the veſſel.

Sulphuric acid, if concentrated and boiling, diſſolves this ſemi-metal; but when the ſolution becomes cold, the calx is precipitated. The nitrous acid calcines the ſemi-metal, and, if aſſiſted by heat, alſo diſſolves the calx. The marine acid, with aſſiſtance of heat, diſſolves both calx and ſemi-metal.

By diſtillation the nitrous acid converts the calx of arſenic into an acid called the Arſenic Acid; the ſame thing is done by dephlogiſticated marine acid: both effects ſeem owing to the attraction which the calx has for vital air; and this acid may by a very ſtrong heat be changed back again into the calx. And hence appears the reaſon why arſenic is ſometimes conſidered as a ſaline ſubſtance, ſometimes as a metallic: but at preſent it is generally reckoned in the latter claſs. The arſenic acid acts upon moſt metallic ſubſtances. If the calx of arſenic be combined with the vegetable alkali, which may be done by throwing a mixture of the arſenic and nitre into a red-hot crucible, the reſult will be what is called *arſenical neutral ſalt:* it fuſes more eaſily, and is more ſoluble in water than the calx: it cannot be decompoſed by any pure acid.

The calx of arſenic unites well with ſulphur, forming artificial orpiment and realgar. It alſo combines well with mineral ſubſtances; in ſuch, however, as poſſeſs metallic brilliancy, it is probable that arſenic, if combined, is in the metallic form. Its union with copper gives the compoſition called *white tombac.* The other combinations have not yet been ſo far brought into uſe, as to obtain diſtinct names.

Arſenic is employed in ſeveral arts. In oil-painting orpiment and realgar are uſed; and a very beautiful green paint may be precipitated from blue vitriol by a ſolution of arſenic calx in water along with vegetable alkali: in dyeing it is employed with ſulphur to diſſolve indigo for printing cloth: in glaſs manufactories it is alſo ſometimes an ingredient, but the glaſs becomes liable to be tarniſhed by air; and it enters into metallic combinations, wherein a white colour is required.

CHAP. XIV.

Of Cobalt and Nickel.

COBALT is a ſemi-metal, of a whitiſh grey colour, inclining to red, nearly eight times as heavy as water, of a fine and compact grain, hard, brittle, and reducible to a powder by pounding. It requires a great heat to fuſe, and cannot be volatilized with any degree of it afforded by furnaces. It is tarniſhed a little by air, but not acted upon by water. It is attracted by the magnet.

Cobalt is found either in the ſtate of a ſimple calx, or in that of an ore united with arſenic. As a calx it is known by its red colour, and is for the moſt part in the form of flowers called Flowers of Cobalt. Its ores are either of a whitiſh grey colour, or the black ore of cobalt. By ſome chemiſts it is ſuppoſed, that with the former, arſenic in the metallic ſtate is combined, and in the ſtate of a calx with the latter.

The manner of treating ores of cobalt is by waſhing, pounding, and roaſting them, for the purpoſe of ſeparating the arſenic, which is collected in a long horizontal chimney. Should any biſmuth be contained in the ore, it is ſeparated at the ſame time by its great fuſibility, and falls in a melted ſtate to the bottom of the furnace. The cobalt remains behind in the form of a dark calx called *zaffre*. This is mixed with about three times its weight of powdered flints; and the mixture being fuſed with about one fourth part of potaſh, produces a dark blue glaſs called *ſmalt*. By the ſame method cobalt may be eſſayed. The ſmalt being thus obtained, is pounded to a very fine powder, or ground in mills, and is afterwards waſhed in a veſſel of water, which has three apertures at different heights, but ſtopped during this part of the proceſs. When the water is fit to be drawn off, it is let out at the higheſt aperture, and contains the fineſt powder of all, becauſe the groſſeſt and weightieſt parts have deſcended to the bottom; and ſo on in the ſeveral gradations to the loweſt, yielding azures of the firſt, ſecond, and third fires. The fineſt azure is employed in ſeveral arts, to give a blue colour to metals, glaſſes, porcelain, and for other beautiful enamels. The coarſeſt is uſed in waſhing clothes, under the name of *powder blue* or *ſtone blue*.

Sulphuric acid, if concentrated and boiling, combines with cobalt, calcining part, and diſſolving part, ſo as to form a cryſtallizable ſalt. The acid diluted acts upon the calx, and yields the ſame ſalt. Nitrous acid alſo combines with the ſemi-metal, with the aſſiſtance of moderate heat. But the marine acid has ſcarcely any action on the ſemi-metal, although it has ſome on its calx. Aqua regia diſſolves cobalt, forming what is called *ſympathetic ink.* If this be diluted with a proper quantity of water, the characters written with it become inviſible, when the ſolution dries; but being afterwards held a ſhort time to the fire, they appear legible, of a fine green colour, which again diſappears by ſuffering the paper to cool. The ſame effect takes place by rubbing over the writing a ſolution of liver of ſulphur in water.

Cobalt is of no other known uſe, than thoſe already mentioned, in which the calx is employed. The reducing of this ſemi-metal is therefore not yet applied to practice.

Nickel is a ſemi-metal, of a whitiſh brilliant colour, inclining to red, nearly eight times as heavy as water; hard and uniform in its texture, ductile and malleable, and requires an intenſe heat to bring it to fuſion. It is for the moſt part united almoſt inſeparably with arſenic, cobalt, and iron, particularly the laſt; and being more and more magnetical, as the proceſſes to ſeparate theſe multiplied, was thought by ſome chemiſts not to be a diſtinct metal, but a combination of others, in which iron predominated. But this opinion is not generally received, becauſe nickel poſſeſſes different properties from any ſuch combination that has ever been made.

The ores of nickel have a red copper colour, which has ſometimes given it the name of falſe copper, and are often mixed with the grey ore of cobalt: from which it can be diſtinguiſhed only when theſe colours are ſufficiently ſtrong; or by a ſlight green on the ſurface of nickel, when that on the ſurface of cobalt is red. Nickel is extracted from its ore by roaſting, to drive off the ſulphur and arſenic contained in the ore: by this proceſs the nickel is left in the form of a greeniſh calx. And if this calx be fuſed with three parts of black flux and ſome common ſalt, the metal is reduced, though probably impure, and containing a portion of arſenic, cobalt, and iron.

Calx of nickel, fuſed with glaſs, impart to it an hyacinth colour more or leſs red.

The ſulphuric acid, diſtilled with nickel, ſends over ſome acid; the reſidue being diſſolved in water, yields a ſalt of a fine green. A ſimilar effect is produced by its action on the calx. This latter is diſſolved by the nitrous and marine acids; and the ſolutions are green.

This ſemi-metal combines with ſulphur by fuſion, forming a hard mineral of a yellow colour. When this is heated ſtrongly in contact with air, it jumps, and emits luminous ſparks, owing to the rapid combuſtion of the nickel by the ſulphur.

Nickel combines cloſely with arſenic, and, by this union, gives a blue glaſs like that of cobalt.

There are no other known uſes of this ſemimetal.

CHAP. XV.

Of Manganeſe, Tungſten, or Wolfram, and Molybdena.

MANGANESE is a ſemi-metal, of a greyiſh white colour, and brilliant in its fracture. It is hard, and ſomewhat brittle, not ductile, and ſo refractory that it cannot be fuſed without a very intenſe heat. In reducing the metal, a metallic button, or rather a number of ſmall globules, is obtained by means of ſuch a heat, managed with the utmoſt care: yet it is one of the metals moſt apt to calcine. Its calx is white, when the calcination is imperfect, but black or dark green, when perfect.

If the black calx of manganeſe be fuſed with glaſs, it gives it in ſome caſes a violet colour: but this admits many modifications, according to the quantity of combuſtible matters employed. In ſome certain proportion of theſe, the mixture becomes colourleſs; and on this account it is employed by glaſs-manufacturers to deſtroy the colours of glaſs. Hence mangaueſe is ſometimes called *ſoap of glaſs*. This change of effect may be explained by the black calx becoming white, either by taking phlogiſton from the combuſtibles, or parting with ſome of its vital air. The ſame calx is made uſe of to give a fine black glaze to earthen ware: it is compoſed of twenty-one parts of white lead by weight, five of powdered flints, and three of manganeſe.

Manganeſe is ſometimes found native; but is for the moſt part in the ſtate of a calx. Its ores are known by their deep grey colour: they are of various kinds, cryſtallized in different ways, and ſome without any regular form, mixed with earths and metallic matters. The ore of manganeſe, known by the name of *black wadd*, is remarkable for taking fire ſpontaneouſly when mixed with an oil. If about one ſixth or one ſeventh part of oil by weight be mixed with a portion of the dry powder, the mixture in a little time becomes hot, and at laſt burſts into flame.

Manganeſe may be reduced from its ore in the following manner. A crucible is lined with charcoal mixed with water, and the mineral in powder being mixed with an oil into a ſort of paſte, is put in the crucible, which is filled with charcoal, and another crucible is faſtened cloſely to this. An intenſe heat is then applied for about an hour, and the manganeſe is found in the metallic form.

The ſulphuric acid diſſolves manganeſe and its calx, yielding a tranſparent vitriol. The nitrous and marine acids alſo diſſolve the regulus, but not the black calx, without the aſſiſtance of ſome combuſtible body, either to impart phlogiſton, or attract its vital air, which reduces it to the white calx or regulus, both which they diſſolve. The marine acid has the ſtrongeſt affinity to manganeſe, being able to decompoſe its ſulphuric ſolution.

This ſemi-metal unites readily with moſt other metallic ſubſtances, except mercury. Gold and iron are rendered more fuſible, and the latter more ductile by the combination. Copper becomes leſs fuſible, and more white, but more ſubject to tarniſh.

The chief uſes of manganeſe have been here mentioned.

Tungſten is a heavy ore, of a greyiſh colour, containing about half its weight of calcareous earth, the remainder iron, and a peculiar acid, which is the metallic calx. Wolfram is a mineral ſtill heavier than the former, containing the ſame acid or calx, united to the calces of manganeſe and iron.

The manner of treating theſe ores is, by pounding them into a ſmall powder, and digeſting this with marine acid: the calcareous earth of the former, and the manganeſe and iron of the latter, will be diſſolved: the reſidue being waſhed, is digeſted with volatile alkali, which unites with the acid or calx. And thus, by alternate application of the marine acid and volatile alkali, the whole mineral is almoſt exhauſted. The acid or calx is ſeparated from the alkali by adding nitrous acid, which precipitates a yellow powder. This colour is a good criterion of ſuch minerals as contain tungſten or wolfram.

From this powder the metal may be reduced by a proceſs ſimilar to the reduction of manganeſe. It is heavier than any metallic ſubſtance, except gold and platina, and is of a dark brown colour.

The calx of tungſten and wolfram combines with many other metallic ſubſtances: but neither theſe combinations, nor this ſemi-metal itſelf, have yet been applied to any practical purpoſe.

Molybdena is a ſemi-metal, of a whitiſh yellow colour, though of a grey fracture. It has only been obtained in ſmall grains, forming together a blackiſh brittle maſs: they are extremely infuſible. By heat it is converted into a white calx, and alſo by the nitrous acid. The ore of molybdena reſembles plumbago. It is found by analyſis to contain ſulphur united with a white calx, which proves to be an acid: this analyſis is made by ſeveral diſtillations of the powdered ore with nitrous acid. And if this calx be combined with ſulphur, a ſubſtance is produced, the ſame in all its properties with the ore.

The acid of molybdena unites with calcareous earth, magneſia, barytes, the alkalies, and precipitates ſeveral metals from their ſolutions.

CHAP. XVI.

Of Uranium, Titanium, Tellurium, and Chromum.

URANIUM is a ſemi-metal of a dark grey colour, ſomewhat brown, in its fracture near $6\frac{1}{2}$ times as heavy as water: it is extremely infuſible, and has been obtained only in very ſmall grains which form a ſpongy maſs. It reſiſts a red heat, and is beſt calcined by nitrous acid, which converts it into a yellow calx.

The mineral Uranium when firſt diſcovered was called Pech-blende, and was taken for an ore of Zinc. But Klaproth found that it conſiſts of a diſtinct peculiar metal mineralized with ſulphur. The ore is of two kinds: the firſt in maſſes of a dark iron grey, and but moderate luſtre, yielding a black powder by being pounded: the ſecond is a deeper black with here and there a reddiſh caſt, more ſhining, having the appearance of pit-coal, and when reduced to powder, tinged with a ſhade of green.

Sulphuric and marine acids act but weakly upon this mineral: but nitrous acid completely decompoſes it, ſulphur and ſiliceous earth falling down: ſo does aqua regia. Theſe ſolutions are precipitated by volatile liver of ſulphur in the form of a browniſh yellow powder: by Pruſſian alkali of a browniſh red: by volatile alkali of a yellow: and by the fixed alkalies of a lemon colour.

The ſemi-metal is reduced from the ore by intenſe heat in crucibles well cloſed; the mineral is then diſſolved in nitrous acid: and afterwards the heat of a porcelain furnace applied to it, united with borax, charcoal, &c. in cloſe veſſels.

Titanium is a ſemi-metal of a browniſh red colour, and conſiderable luſtre: it is brittle, hard, and very infuſible. By a very ſtrong heat it loſes its luſtre, and falls to pieces. If mixed with five times its weight of vegetable alkali, it melts in a porcelain furnace, and when cold forms a grey maſs, the ſurface of which is cryſtallized. This being waſhed in boiling water, the alkali is diſſolved and a white powder falls to the bottom which is the calx of titanium. When heated on charcoal, it aſſumes firſt a roſy red, afterwards a ſlate blue, and at laſt melts, but without being reduced to the metallic ſtate. This ſemi-metal has no affinity to ſulphur. Its mineral has been called red ſhorl.

Tellurium is a ſemi-metal of a white colour like tin, but ſomewhat darker. It is very brittle, crumbling, and fuſible as lead. By ſtrong heat, it burns with a lively blue flame, and volatilizes entirely in a whitiſh grey ſmoke, which is its calx: this may alſo be obtained by diſſolving the metal in aqua regia, and precipitating it with a quantity of water. If this calx be mixed with any fat oil, and diſtilled in a retort, the metal is reduced in the form of brilliant drops, which fall from the upper part to the bottom of the retort. This ſemi-metal combines with ſulphur, and amalgamates with mercury.

The mineral of tellurium is found by Analyſis to contain in 1000 parts, 2½ of gold, 72 of iron, 925½ of tellurium.

Chromum is a ſemi-metal lately diſcovered in a red lead ore. It is grey, hard, brittle, and cryſtallizes in needles. It poſſeſſes the property of giving colour to other bodies in a remarkable degree.

CHAP. XVII.

Of the Combuſtible Subſtances, called Bitumens.

BITUMENS are combuſtible ſubſtances, which ſometimes appear in a fluid form reſembling oils, at others more thick and tenacious like tar, and at others quite ſolid. They are found either forming layers in the heart of the earth, or dropping through rocks, or ſwimming upon the ſurface of waters.

The principal of theſe bitumens is *Pit-Coal.* This well known ſubſtance is found diſpoſed either in horizontal or for the moſt part inclined layers; and frequently under great beds of ſhells. When analyzed by diſtillation, pit coal is proved to contain one eighth part of liquid matter, partly oil and partly diluted acid, an elaſtic air, and a reſidue which reſembles a ſubſtance prepared from pit coal as an article of trade, called *coak or cinder.* This preparation is of conſiderable ſervice in the fuſion of metals; becauſe it affords an intenſe heat, and alſo is free from thoſe oils and other volatile matters, which make the coal run or cake into maſſes, and in ſo doing greatly injure the proceſs. In preparing coak, theſe volatile ſubſtances formerly were entirely loſt: but they are now ſaved by means of a certain apparatus in which the coals decompoſe themſelves by a ſlow combuſtion: and they are made into tar or pitch for ſheathing the bottoms of ſhips. It is by this oily and bituminous matter that Pit coal is chiefly diſtinguiſhed from *Stone Coal:* and it is probably owing to the great quantity of it contained in *Cannel Coal*, that this burns ſo bright as to enable the country people to work by its light, ſupplying thus the place of candles: and this, as Biſhop Watſon thinks, may have given its preſent name to the coal, candles being called, in the dialect of Lancaſhire, cannels.

There is a ſubſtance called *Culm*, which reſembles in its appearance the powdery part of pit coal, but does not poſſeſs the property of running together or caking like this: and on this account they may eaſily be diſtinguiſhed from each other. The reaſon probably is, that culm does not abound ſo much in oily and bituminous matter as pit coal. It is chiefly uſed in burning lime.

Kilkenny Coal is a ſtone coal which abounds with ſulphureous matter: its vapour therefore, when confined, is moſt noxious and ſuffocating; and has in many inſtances proved fatal to perſons ſleeping in chambers, where it was burnt.

Amber is another of thoſe bitumens: but having already taken notice of this ſubſtance, it will not be neceſſary to ſay more of it here.

Aſphaltum, called likewiſe Jews pitch, gum of funerals, mountain pitch, &c., is a black heavy, ſolid, and brilliant bitumen. It is thrown up from the bottom of the dead ſea like a liquid pitch to the ſurface, and is condenſed by the heat of the ſun. The Arabs gather it, when thrown upon ſhore. Its origin, like that of many of the reſt, is diſputed: but probably it is of the ſame nature with amber, except that it ſeems to have undergone the action of ſubterraneous fire. Aſphaltum is employed by the Arabs and Indians as a covering for ſhips: it makes part of black varniſhes for china: and is uſed in artificial fires which burn on waters. The poorer people of Egypt embalm the dead bodies with it.

Naphtha and *Petroleum* are fluid bitumens. They are reckoned by ſome chemiſts to be of the ſame kind, and alſo to be aſphaltum in a liquid ſtate. Naphtha is pale, light, and very inflammable ſo as to burn even under water: petroleum is yellow, brown, or blackiſh, heavier and leſs inflammable than naphtha.

Various other bitumens may be mentioned, ſuch as *mineral pitch* or *Barbadoes tar*, *jet*, *turf*, &c. &c.: but thoſe already noticed ſeem moſt important. Some chemiſts ſuppoſe theſe bitumens to belong to the mineral kingdom: but the more general opinion ſeems to be, that they are derived from the bodies of vegetables and animals. Peat and turf evidently owe their combuſtible qualities in a great meaſure to the roots of vegetables mixed with them. Pit coal too very probably owes its inflammability to the ſame cauſe, for by analyſis it yields oily and other matters ſimilar to thoſe contained in vegetables. Whole trees and even woods are found converted into pit coal; in which the roots, trunks, branches, &c. &c. are clearly diſcerned; and hence it is moſt likely that the bitumens owe their origin to great tracts of wood buried in the earth by volcanos, earthquakes, and other convulſions of nature.

CHAP. XVIII.

Of Mineral Waters.

AFTER this ſhort view of the bodies, which compoſe the mineral kingdom, we ſhall conclude the account by ſome remarks upon the *Mineral Waters*, ſo called becauſe they are impregnated, more or leſs with thoſe mineral ſubſtances. The ſeveral kinds of theſe may be reduced under four principal heads; 1ſt, the gaſeous or acidulous, 2ndly, ſaline waters, 3rdly, ſulphureous, 4thly, ferruginous. The *Gaſeous or Acidulous waters* are thoſe in which are found certain elaſtic gaſes, particularly fixed air, or aerial acid. They are ſometimes diſtinguiſhed by the ſharpneſs and briſkneſs of their taſte; by their forming bubbles with agitation, or by tying a wet bladder to the neck of the bottle which contains them, for by ſhaking the water, the gas being diſengaged will ſwell the bladder. The advantage of this laſt method is that the nature of the gas can be examined, when thus diſcovered. This kind of mineral waters ſeldom contain the acid alone, but for the moſt part alkali and calcareous earth, and ſometimes iron, of all which it is a ſolvent. 2. *Saline waters* are thoſe which contain a quantity of ſalts. Theſe ſalts are for the moſt part of the neutral kind; but are ſometimes acid or alkaline. A cave near the town of Latera about 30 miles from Viterbo is mentioned, where a pure ſulphuric acid, though much diluted, iſſues through the crevices of the rocks: the cave is filled with noxious vapours, and cannot be entered with ſafety, except at particular times. The alkalies alſo are occaſionally found to predominate in mineral waters, though ſeldom or never without aerial or ſome other acid.

Glauber's ſalt is contained in ſome mineral waters, though in ſmall quantity. Two ſprings are mentioned however, one near Madrid, the other at Sellia in Calabria, which contain it in abundance: from the former it is procured by ſimple evaporation, and the latter abounds with it ſo much that it would probably be worth obtaining as an article of trade.

Common nitre is an ingredient in ſome mineral ſprings in Europe: but in the provinces of Bengal in the Eaſt Indies, the waters muſt be ſtrongly impregnated with it, the ſurface of the earth being ſometimes covered with it as with a hoar froſt.

Calcareous earth, and Magneſia diſſolved by the aerial acid are frequently found in mineral waters, and in common waters eſpecially thoſe which are hard. Theſe waters being boiled, the fixed air evaporates, and of courſe the earths which it held in ſolution fall to the bottom: hence the cruſt formed upon tea kettles. The ſame effects take place from long expoſure to the air: the water ſoftens, and petrefactions are formed upon ſubſtances immerſed in ſuch of them as are very ſtrongly impregnated with theſe ſubſtances.

The moſt common ſaline ingredients in mineral waters are Epſom ſalt, ſea ſalt, gypſum or ſelenite, calcareous marine ſalts, and ſalts with baſe of magneſia. Theſe are for the moſt part intermixed with each other, as well as with other ſubſtances, ſuch as iron and ſulphureous matters.

3rdly, *Sulphureous waters* are thoſe, which ſeem to poſſeſs the properties of ſulphur, and therefore are by ſome chemiſts thought to contain ſulphur in ſolution. Theſe waters are very clear at the ſpring, but when kept in open veſſels, ſoon depoſit ſulphur and loſe thair hepatic ſmell. Sulphur has been alſo obtained from waters of this nature by evaporation and otherwiſe: which gave colour to the opinion above mentioned. But ſulphur not being of itſelf ſoluble in water, the moſt prevailing opinion now ſeems to be, that they are impregnated with the vapour which iſſues from liver of ſulphur. Theſe waters may be imitated,

tated, by impregnating common water with this hepatic gas; and as the depoſiting of ſulphur may be explained according to this hypotheſis, it ſeems to be leſs liable to difficulty than the other. However ſome waters may poſſibly contain a ſmall quantity of hepar, while others contain only the gas.

4thly, *Ferruginous or Chalybeate Waters* are thoſe, which are impregnated with iron, ſuppoſed to be diſſolved by the aerial acid. Iron is not found alone in waters: it is mixed with chalk, ſelenite, marine ſalts, magneſia, lime, or the alkalies. But as the metal is the chief ingredient from which their properties are derived, they are called by the name here given them, and alſo *martial waters.* It frequently happens that waters, which contain iron diſſolved by the aerial acid, taſte ſtrongly chalybeate at the ſpring, but loſe this taſte entirely after running ſome way. This is owing to the Acid being more ſtrongly attracted by earth, and the iron precipitating, as being no longer held in ſolution.

Iron is ſometimes found in mineral waters combined with ſulphuric acid, but generally in ſo ſmall quantity and ſo fine a ſtate, as not to be diſcovered in the uſual method of analyſis by diſtillation: but may by teſts.

Different methods of examining mineral waters are practiſed, either by their phyſical properties, by teſts, by evaporation, or by diſtillation. Of theſe we ſhall for the ſake of ſhortneſs take notice

tice of a few only of the moſt important inſtances of examination by teſts. Teſts are ſubſtances, which by their greater affinity to ſome of the conſtituent parts of mineral waters than theſe have to each other, decompoſe them, and thus diſcover the nature of the ingredients diſſolved in the waters.

Lime-Water is one of the moſt uſeful teſts: it decompoſes the metallic ſalts, eſpecially martial vitriol, and precipitates its iron: for the ſulphuric acid has a ſtronger attraction to lime than iron. In the ſame manner it precipitates clay and magneſia from the ſulphuric and marine acids, with which theſe ſubſtances are frequently joined in mineral waters. It alſo ſhews the preſence of the aerial acid, which readily combines with the lime, and precipitates it in the form of chalk. As common chalk contains nearly one half its weight of this acid, it may be known how much of the acid is contained in the precipitate, by comparing its weight with that of common chalk.

Fixed Alkali in a cauſtic ſtate is another of theſe teſts. It decompoſes all ſalts formed by the union of acids with lime, clay, magneſia, and the metallic ſubſtances. It alſo ſhews the preſence of chalk, which is kept in ſolution by a great abundance of aerial acid, to which acid the cauſtic alkali having a ſtrong affinity, will attract a great part of it; by theſe means the chalk is no longer held in ſolution, but falls to the bottom.

Volatile cauſtic Alkali is a more certain teſt than the former: becauſe where ſo great a number of ſalts are capable of being decompoſed, it becomes more difficult to know the ſubſtance precipitated. Volatile alkali decompoſes no earthy ſalts but thoſe of clay and magneſia. This alkali ſhould be freed perfectly from all fixed air, for otherwiſe it will decompoſe calcareous ſalts by double affinity; and for the ſame reaſon it ſhould not be expoſed in open veſſels, as it will attract this air from the atmoſphere. The beſt method of uſing this teſt is by applying to it a gentle heat in a retort, whoſe neck is immerſed in the mineral water to be tried: an alkaline gas paſſes over, and if there be any precipitate, the water contains martial vitriol; or ſalts, with baſe of alumina or clay, or magneſia. The firſt of theſe is eaſily diſtinguiſhed by the colour; and the magneſia is diſtinguiſhed from the alumina by a much quicker precipitation.

Concentrated Sulphuric Acid is ſometimes uſed as a teſt. It precipitates barytes, and ſhews the preſence of chalk, of fixed alkali, or of fixed air by forming bubbles. If chalk be the chief ingredient, the water, if heated, will upon receiving the teſt, form a pellicle, and depoſit ſelenite; which does not happen in alkaline waters.

Concentrated Nitrous Acid is a good teſt to try ſulphureous waters; for it will precipitate ſulphur, even though the water ſhould be impregnated only with hepatic gas, as is manifeſt from trying it with diſtilled water ſo impregnated.

The Gall-Nut, as well as all bitter and aſtringent vegetable ſubſtances, as oak-bark, green tea, &c. precipitate iron, giving to its ſolutions different colours, from a pale roſe to the deepeſt black, according to the quantity and ſtate of the iron. Gall-nut is better for this purpoſe in the form of a cold infuſion tinctured with ſpirit of wine, than as a powder: a ſingle drop gives a purple colour to water, containing only the proportion of one grain of martial vitriol in nine gallons of water.

In employing theſe and other teſts, Mr. Fourcroy recommends that large quantities both of the waters and teſts ſhould be uſed—that the teſts ſhould be continued, till no more precipitate can be obtained—that the precipitates ſhould remain twenty-four hours in a veſſel cloſely ſhut—that the mixture be then filtered, and the precipitate examined by the uſual methods, after it has been weighed and dried. He thinks too that a certain order ſhould be obſerved, by firſt uſing ſuch teſts as are leaſt capable of altering the waters, and then advancing from theſe ſubſtances to others which are able to produce the greateſt and moſt various changes.

The following liſt contains a few of the moſt noted mineral waters, both hot and cold; together with the principal ſubſtances with which they are mineralized.

Aix-la-Chapelle contains chalk, ſea-ſalt, mineral alkali, and hepatic gas: hot.

Ballynahinch—Iron, fixed air, and hepatic gas: cold.

Ballyſpellin—Iron, fixed air, and probably mineral alkali: cold.

Bareges—Sea-ſalt, mineral alkali, calcareous earth, ſelenite, hepatic gas, and a fine bituminous oil: hot.

Bath—Iron, chalk, ſelenite, ſea-ſalt, and Glauber's ſalt: hot.

Briſtol—Lime, ſea-ſalt, Epſom ſalt, Glauber's ſalt, and ſelenite: hot.

Buxton—Mineral alkali, Epſom ſalt, a little ſea-ſalt, and chalk: hot.

Caſtleconnell—Iron diſſolved in fixed air: cold.

Cheltenham—Lime, iron, Epſom ſalt, and common ſalt: cold.

Epſom—Vitriolated and muriated magneſia, with a little chalk.

Harrowgate—Hepatic gas, ſea-ſalt, and ſome purging ſalt.

Lucan—Hepatic gas, and foſſile alkali.

Mallow—Similar to Briſtol.

Pyrmont—Iron united to fixed air, calcareous earth, magneſia, Epſom ſalt, and common ſalt.

Scarborough—Chalk, Epſom ſalt, ſea-ſalt, and iron.

Seltzer—Lime, magneſia, mineral alkali, and fixed air.

Spa—Iron with fixed air, chalk, magneſia, mineral alkali, and common ſalt.

Swadlingbar—Hepatic gas, earth, ſea-ſalt, and mineral alkali.

Tunbridge—Iron, ſea-ſalt, ſelenite, and calcareous earth.

Artificial waters are made in imitation of ſeveral of theſe by ſyntheſis. Thus Harrowgate water, which contains ſea-ſalt and ſulphur, may be imitated, by impregnating ſalt water with an air diſengaged by ſulphuric acid from melted lead, and other ſubſtances which give out ſulphureous gas.

SECT. IV.

Of Vegetable Subſtances.

CHAP. I.

Of the Juices and extracts of Vegetables.

TO treat of vegetable and animal ſubſtances may ſeem at firſt to claſh with the general definition of chemiſtry already given, whoſe province was there limited to inanimate matter. A little conſideration however will reconcile this: for though chemical changes do actually take place in the circulating as well as ſecreted fluids of both thoſe ſubſtances, yet theſe are merely accidental, *not depending on*, though even eſſential to the life of ſuch bodies. For the proof of ſuch changes we are indebted to mere analogy, deduced from experiments made on ſuch ſubſtances when ſeparated from the bodies, wherein they had been formed, ed, that is, when inanimate. Now thoſe experiments are truly chemical, while the analogy is but an inference drawn from them, and applied to animated matter: which mode of inference, combined with phyſical, mechanical, and other principles, conſtitute that branch of medical ſcience, called *phyſiology*; and it was thought right to diſtinguiſh chemiſtry from this in the ſtrict meaning of the terms.

Vegetables are organized ſubſtances which are nouriſhed by juices received by and prepared within their veſſels: and which are capable of being reproduced and propagated by ſeeds. In theſe reſpects, as well as in their curious and beautiful organization, they are diſtinguiſhed from the mineral kingdom; between which and the animal kingdom, they hold as it were a middle place; differing from the latter in their confinement to one particular ſpot on the ſurface of the earth, without any power of changing their place, and without any apparent ſenſibility.

There are various methods of chemically examining vegetable ſubſtances; by inciſion of the rind or bark of the living plant; by ſimple preſſure, by the action of fire in a weaker or ſtronger degree of heat: by ſpontaneous decompoſition or fermentation.

Thoſe principles of vegetable ſubſtance which poſſeſs no ſaline qualities or poſſeſs them very ſlightly, are called *juices*, when they flow from inciſion, or are obtained from mere preſſure:

and they are called *extracts*, when by evaporation of the water contained in them they are rendered more thick and conſiſtent. They are chiefly as follow: 1ſt, Gum or Mucilage. This is a well known ſubſtance, inſipid, and ſoluble in water, to which it gives a thick and gluey conſiſtence. It is uſually obtained by making inciſions in the barks of trees, ſuch as plumb, pear, cherry, &c. &c. gum Arabic flows from the Acacia in Egypt and Arabia. Gum ſeems to have a ſtrong analogy to ſugar: for they both yield the ſame products by diſtillatiou. 2nd, Saccharine juices or ſugar. Theſe are found in many vegetables: but the ſugar cane a native of the Indies, contains the greateſt quantity of them. Theſe canes, when ripe, are preſſed between iron cylinders placed upright. The juice thus extracted is boiled, and a little alum with ſome quick lime in powder, which is called *temper*, is poured in, for the purpoſe of uniting with the ſuperabundant acid and collecting the impurities. In this boiling, the heat is ſuffered to increaſe gradually to near the degree of boiling water; for a ſudden and violent heat would mix the impure matters inſtead of ſeparating them. Theſe are ſoon collected on the top in the form of a ſcum, and the purified liquid is let off below into an other veſſel, where it undergoes a ſimilar proceſs, which is repeated four times, After this, the liquor is cooled and poured into barrels, with holes in the bottoms imperfectly ſtopped. The greater part of the ſyrup becomes ſolid in the barrels, while the fluid part runs through the holes into a ciſtern, over which the barrels are placed. In this ſtate the ſolid part is called *Muſcovado, or raw ſugar*. This ſugar, is in ſome degree, refined in the Weſt Indies by boiling it again, and pouring it into earthen veſſels ſhaped like a ſugar loaf, turned down upon their tops: in which veſſels there are holes to let out the fluid which is not ſufficiently conſiſtent: which fluid is called *thick ſyrup*: the bottom of the loaf is taken off, ſome fine white ſugar put in its place, and the whole covered with pure wet clay, the water of which filters through, carrying off with it what is called the mother-water of the ſugar through the holes into pots: this fluid is called *fine ſyrup*. The proceſs is repeated, after which the loaves are broken, and the ſugars thus made are ſhipped for Europe; where they are further refined by boiling the ſugar in lime-water along with bullocks blood. Theſe ſubſtances attract all the earthy and impure ſubſtances, and carry them to the ſurface, whence they are ſkimmed off. The purified liquor is then either poured into moulds, where it forms *loaf ſugar*; or elſe it is expoſed in heated rooms, where by a gradual and regular cryſtallization it forms *ſugar candy*. The ſyrups, which after all the proceſſes cannot be farther cryſtallized, are called *melaſſes*; they are uſed by poor people inſtead of ſugar; are ſometimes diſtilled into an ardent ſpirit: and are alſo employed by the Dutch in the manufacture of tobacco.

3. Farinaceous juices, or extracts.—Of all theſe the moſt important to be examined is that of wheat: it is compoſed of three different ſubſtances, which are thus obtained—The farina, or flour of wheat, is mixed with water into a kind of paſte—this is ſqueezed and worked in the hands, while a gentle ſtream of water is made to paſs through it into a veſſel, and continues to do ſo until the water, from a whitiſh and milky appearance, becomes clear. There is found then in the hands a tenacious, ductile, and elaſtic matter, called *gluten*—when drawn out, it can be extended to near twenty times its length; and upon being let looſe reſumes its former bulk. If expoſed to a hot fire, it bubbles and cracks; but with a gentle heat dries well, and becomes ſomewhat tranſparent, hard, and brittle like common glue—when freſh, and expoſed to a warm moiſt air, it changes and putrifies like animal ſubſtances. If all the white flour be not waſhed away, cheeſe of moderate fineneſs can be prepared from it.—It is from this gluten wheat flour derives its properties of making a pliant good paſte, and the readineſs with which it riſes in bread. At the ſame time, fermentation always entirely deſtroys the vegetable gluten, and even unfermented bread ſuffers the ſame change by fire.—This gluten is not found in any quantity in other farinas, as oats, rye, &c.

The next of theſe three ſubſtances is *ſtarch;* which is found in the bottom of the veſſel: it is very fine, ſoft to the touch, and without any ſenſible taſte. The uſual method of preparing ſtarch for domeſtic uſes is, from coarſe flour, or from bran: which is ſteeped in water for two or three days, till it becomes ſour: it is ſtrained through ſieves, and freſh water ſupplied, and renewed every day—in a ſhort time a yellowiſh ſcum appears on the ſurface, which muſt be carefully removed. After ſome days bleaching in this manner it is tied in a cloth, hung up to drain, and then cut into ſlices, which are dried in the ſun, or an oven moderately heated. Starch, in this ſtate, being powdered and ſifted, makes hair-powder.—It is not ſoluble in cold water; but if boiled in water forms a kind of glue, which, when expoſed to moiſt air, ferments and becomes mouldy.—Starch is the principal ſubſtance in bread: for it forms the greateſt part of the farina.

The laſt of theſe three ſubſtances is found in ſolution in the water: and by evaporation appears to be a browniſh yellow matter, of a gluey conſiſtence, and a weak taſte of ſugar. It does not materially differ from gums or mucilages. Probably this ſubſtance like the firſt, has a conſiderable ſhare in the fermentation and riſing of the paſte in making bread. Good flour conſiſts of $\frac{4}{10}$ vegetable gluten, and $\frac{6}{10}$ farina.

There is yet another ſubſtance, that has been lately diſcovered by Fourcroy, called *vegetable Albumen*: it is found in the juices of certain vegetables, particularly of citron; it paſſes readily to fermentation, and by the action of the alkalies yields volatile alkali.

CHAP. II.

Of the Oily and Reſinous Principles of Vegetables.

VEGETABLE OILS are diſtinguiſhed into fat oils and eſſential oils: the former are obtained by preſſure from the fruits, ſeeds, or kernels of vegetables; the latter either by preſſure, or by infuſion, or by diſtillation of the different parts of the plants. The method of procuring oils by preſſure, is commonly by pounding the vegetable matters in a mortar, and then forcing out the oils with a preſs. It is of great uſe to avoid the action of heat in preparing theſe, as it makes them rancid, and by this injures them in their medicinal uſe. If the vegetable matters be too dry for this proceſs, they may be ground into meal, and ſuſpended to receive the ſteam of boiling water, which ſoftens them ſufficiently for the foregoing method.

1. Fat oils have a mild taſte and ſmell, and are very ſmooth to the touch. When heated to the degree of boiling water, they are ſet on fire; and

by raiſing the heat higher, they become volatile. This explains the burning of lamps or candles; for the wick attracts the oil through its little tubes or hollow threads up to the fire, where it becomes ſo far heated, as to be inflamed and volatilized. Fat oils, when poured out, make much leſs noiſe than water, being leſs elaſtic. They are not eaſily diſſipated by the heat of the atmoſphere, and therefore leave a greaſy ſpot upon porous ſubſtances, into whoſe pores they inſinuate themſelves; but they become ſtrong and rancid by expoſure to air, owing to their combination with vital air. If diſtilled, they afford a ſmall quantity of water, a light oil, a denſe oil, inflammable air, and fixed air. The reſidue conſiſts of a ſmall quantity of charcoal. *Drying oils*, which are uſeful in painting, are prepared by boiling them, and ſo evaporating all their mucilage.

Fat oils combine with various ſubſtances: with metallic calces, they form what are called metallic ſoaps; with pure fixed alkali, common ſoap; with mineral alkali, imperfect ſoaps; with ſulphur, compounds called Balſams of Sulphur; with bitumens and amber, they make varniſhes. Olive oil contains in 100 parts, 78 pure charcoal, 22 inflammable gas. The pureſt oils contain mucilage, which abſorbs vital air, and makes them rancid.

2. Eſſential or volatile oils differ from the former: their ſmell is ſtrong and aromatic; their taſte hot and biting. They are found in almoſt

all fragrant vegetables, and are ſometimes obtained by preſſure; as from citron, bergamot, oranges, lemons: ſometimes by infuſion, or decoction, when the plant is boiled a conſiderable time in water: but they are for the moſt part obtained by diſtillation with water—the plants are cut ſmall, well ſteeped in water, and put into the ſtill: what comes over by the proceſs is called a *ſimple diſtilled water*. Some plants, however, are ſo tender, that it is better only to expoſe them to the ſteam of boiling water; for which purpoſe a piece of hair cloth is ſpread above the water in the ſtill, and the plants laid upon this: as the ſteam aſcends, it paſſes through the plants, and diſſolves their eſſential oils.—Lavender and roſemary for inſtance, give a much finer and more fragrant oil, or diſtilled water, by this method.

Some eſſential oils are heavier than water, and of courſe ſink to the bottom of that which comes over with them in the proceſs; ſuch as thoſe of cinnamon, cloves, ſaſſafras, &c. and other foreign plants—the reſt, being lighter, ſwim at the top.

The aromatic parts of plants ſeem to be diſtinct from the general matter of the plant: for when examined with a microſcope, there are found a number of ſhining particles, which being removed, the plants have no aromatic oil. Theſe particles conſtitute what is called *aroma*: it is decompoſed by dephlogiſticated marine acid, and is inflammable, as appears from its taking fire in ſome plants: it combines with fixed oils, and is ſoluble in alcohol and water.

The eſſential oils are ſometimes adulterated, either with fat oils, or with rectified ſpirit of wine, or with inferior eſſential oils. In the firſt caſe, the fraud may be detected by mixing a little ſpirit of wine with a few drops of the ſuſpected oil, and ſhaking them together: the ſpirit will diſſolve the eſſential, but not the fat oil.—Another method is, by dropping the ſuſpected oil on paper, and holding this over a candle: the eſſential oils evaporate, and the fat oils leave a ſtain behind.

In the ſecond caſe, by putting a few drops of the oil into clear water, which will become white; and by continuing to ſhake the glaſs, the water will abſorb the whole ſpirit, leaving the oil pure at the top.

In the third caſe, as when oil of turpentine is mixed, if a bit of cloth be ſteeped in the oil, and held to the fire, the aromatic ſcent flies off, leaving that of turpentine behind. Eſſential oils are highly inflammable. Combined with ſulphur they compoſe balſams: with ſulphuric acid, bitumens. Gums and ſugar render them ſoluble in water—in medicine, both fat and eſſential oils are of conſiderable uſe.

Camphor is a concrete oily ſubſtance, which is extracted from a kind of laurel, or bay tree, growing in China—it reſembles eſſential oils in ſome reſpects, and may be depoſited from them—it has a bitteriſh aromatic taſte, and fragrant ſmell, ſomewhat like roſemary, but much more powerful—it is extremely volatile, ſo as not to be preſerved except in cloſed veſſels; and even in theſe it ſublimes in the heat of ſummer—and will for ſeveral days impregnate a room, at the ſame time loſing weight.

The method of obtaining camphor is, by chopping the wood and other parts of the tree very ſmall, and ſteeping them for ſome days in water—they are then boiled and ſtirred continually till a ſap, like hoar froſt, appears on the ſtirring-ſtick; when the maſs is carefully ſtrained, and ſet to ſtand—after a night's repoſe it is found in a ſolid form, and is then diſtilled along with about a twelfth part of lime.—This laſt proceſs being repeated, the camphor ſublimes in ſmall whitiſh grains.

Camphor is diſſolved largely in ſpirit of wine, ether, and very ſtrong acids.—If water be added to theſe ſolutions, it ſeparates the camphor from them, but does not diſſolve it. Fat and eſſential oils, with the aſſiſtance of heat, diſſolve and cryſtallize it.

Camphor, if cautiouſly adminiſtered in medicine, is ſometimes of great ſervice, by its ſedative quality; which is ſo powerful as to procure ſleep in caſes where opium had failed.

3. *Reſinous juices* uſually flow from inciſions made in the trunks of trees for the purpoſe.—Thoſe of the fragrant kind, when thickened, are called balſams: which may be conſidered as eſſen-

tial oils, whoſe finer and more volatile parts have been exhaled: for thoſe oils are by exhalation converted into ſimilar ſubſtances—the other kinds are called reſins—reſins are ſoluble in ardent ſpirit; they are not ſoluble in water, a circumſtance important to be known in the art of dyeing—they are inflammable, but not ſo volatile as the eſſential oils: for in cloſe veſſels they do not, like theſe, riſe wholly, but are decompoſed by heat.

Reſinous juices flow from different ſpecies of the pine.—Chio, or Cyprus turpentine, from a tree which grows in Spain, France, and alſo the iſles of Chio and Cyprus; Venice turpentine from the larch tree; common turpentine from the Scotch pine, is obtained by making the reſinous juice paſs through a baſket: and if the thick matter, which remains behind, be diſtilled with water, oil or ſpirit of turpentine comes over, and may be ſkimmed off the ſurface of the water on which it ſwims—when all the oil is obtained, the reſidue in the retort is common yellow reſin.

Tar is made from the wood of the pine:—the wood is piled up, covered with turf, and ſet on fire: the oil not being able to paſs through the turf, is conveyed into veſſels by means of gutters. If boiled for a while, without adding any thing, and let to flow out, it is what is called common pitch. But the white, or Burgundy pitch, flows from the tree by inciſion, is ſqueezed through linen cloths, and received into caſks.

Gum reſins are juices mixed with reſins and gum: part of them only is diſſolved in water, ſpirit of wine, wine and vinegar.—A few of the principal of theſe are, aſſafetida, of a ſtrong nauſeous ſmell and taſte—it is extracted from a Perſian plant. Aloes is a juice of a deep reddiſh brown colour, and bitter taſte—it is from a Spaniſh plant. Myrrh is brilliant and reddiſh, of a ſtrong agreeable ſmell, and pleaſant taſte. Elaſtic gum is extracted from a tree, which grows in America: the juice is applied upon moulds, in different layers, and afterwards dried in ſmoke.

CHAP. III.

Of the Colouring Matters of Vegetables.

THE extracts of vegetables, called their colouring matters are of great importance to be known: becauſe upon the knowledge of them, the uſeful and beautiful arts of painting and dyeing in a great meaſure depend. The proceſſes of theſe arts, ſo far as relates to the preſent ſubject, are founded upon the ſolubility of the colouring matters in different fluids; upon their different affinities; upon the manner of applying them to the bodies to be painted or dyed; and upon the means of rendering the colours permanent and laſting. It ſhould here be obſerved that the colouring matters of animal ſubſtances as well as vegetable will be taken into conſideration.

There are ſeveral colouring matters of ſuch a nature as to be eaſily diſſolved in water, and which will ſtain cloth while it remains in their ſolution, but the colours are very fading, when obtained merely in this way. Such are thoſe of cochineal, kermes, gum lac, madder, dyer's wood, Indian wood, Brazil wood, logwood; which furniſh red or yellow colours of this ſort. Thus as ſoon as cloth dipped in a ſolution of cochineal is taken out and waſhed, the red colour will vaniſh, and the cloth be nearly the ſame as before it had been dyed.

To remedy this defect, acid ſalts are in general employed for fixing theſe fugitive colours. Thus if the cloth be dipped in a ſolution of alum (which conſiſts of ſulphuric acid united to its earth) and afterwards be immerſed in the ſolution of cochineal, it will come out permanently coloured; and the colour will not be diſcharged even by waſhing with ſoap and water. This effect is ſometimes explained by ſuppoſing the colouring parts to be of a ſoapy nature; ſo that when the acid comes in contact with them it ſeizes the alkaline particles of the colouring matter, ſetting free the reſt which are reſinous, and precipitating them upon the cloth. Others call this effect a coagulation ſimilar to what takes place in ſeparating the curd of milk from the whey: which perhaps does not greatly differ from the former. The colours thus obtained, by means of ſome other ſubſtance precipitating the colouring matter, were uſually called *Lakes*: the ſubſtances ſo employed are now called *Mordants*. And the explanation now given of the proceſs ſeems to be; that the mordant has an attraction both to the cloth, and to the colouring matter; by means of which it ſerves as a bond of communication between both. For inſtance, the earth of alum is fixed upon the cloth by its immerſion in the ſolution of alum, which has an attraction for the cloth: and the ſame earth has alſo an attraction for the colouring matter, which by means of this is fixed upon it after precipitation.

Theſe apparently different accounts may be reconciled by ſuppoſing (what is probably the caſe) a two-fold operation to take place; one in which the earthy baſe has a part, the other, in which the acid is employed. For that this acid is ſeparated from its baſe is evident from another proceſs, which is thought greatly to improve the former: and that is, to add a quantity of tartar to the ſolution of alum. The tartar ſerves two purpoſes; firſt, its alkali combines with the ſulphuric acid of the alum, and ſo prevents the cloth from being corroded by it; and ſecondly, the acid of tartar combines with the earth of the alum which union is more eaſily decompoſed by the cloth, than the alum is. And the ſame thing appears from another improvement in the proceſs, which is made by mixing ſugar of lead with a ſolution of alum: a double attraction takes place, the ſulphuric acid uniting with the lead falls down in an inſoluble powder, while the acetous acid combines with the earth of alum, and remains diſſolved.

There are other mordants beſide alum, as metallic calces, oil of vitriol, tartar, ſalt, ſal ammoniac, tan, oil, &c. But of all theſe the moſt valuable is the ſolution of tin in aqua regia, which is found to give moſt colours a very high degree of beauty, and ſome permanency to the moſt fading. It is by means of this alone that ſcarlet, the brighteſt of all colours is produced: which is done with cochineal, tartar, and ſolution of tin in aqua regia: the cochineal giving a crimſon colour, the tartar having the property of changing the cochineal to yellow (which two colours compound the ſcarlet) and the ſolution of tin giving to the whole a bright, and beautiful ſplendour. Brazil wood yeilds by ſolution of tin a purpliſh crimſon, logwood a dark purple; but it deſtroys the colours of madder, ſaflower, archil, and tincture of roſes.

The moſt permanent colours for fine reds are cochineal and gum lac: madder and kermes for coarſer reds: weld and ſome other vegetables for yellow. It is to be obſerved that woollen cloths are moſt eaſily dyed, and take the beſt colours of this kind next to thoſe; ſilk, then cotton, and laſt of all, linen: and that the two laſt having a weaker affinity to earth of alum, than wool or ſilk, require mordants, which, like the improvements abovementioned, ſhall ſeparate the ſulphuric acid from that earth, and ſo render the combination of this with the cloth the eaſier.

Wool in fleece is ſeldom dyed ſcarlet, for two reaſons; firſt, becauſe in fabricating the cloth, in ſpinning, twiſting and weaving, ſome other coloured wool might mix with it, and ſo injure the colour; and ſecondly, becauſe being heightened with an acid, it cannot well endure the proceſs of fulling, in which alkaline ſoaps are employed. Theſe reaſons apply to a certain extent to all the ſimple colours viz. blues, yellows, reds, and blacks: and particularly to ſuch of them as have been obtained by acid mordants.

The principles now laid down may alſo be applied to obtain colours of this ſort for painting: of which the following inſtances may be ſufficient. If about a pound of turmeric root, three pints of water, and an ounce of ſalt of tartar, be boiled together over a gentle fire, till the water ſtains paper a beautiful yellow; and if the liquor be then filtred, adding to it by degrees a ſtrong ſolution of alum in water, till the yellow matter is precipitated; this precipitate, after it be well waſhed and freed from water, is the yellow paint called *lac of turmeric*. It is ſo called from gum lac one of the firſt invented, and fineſt of this ſort, affording a beautiful red. Again, let calx of tin with alum be well rubbed together in a glaſs mortar, ſo as to mix the ſubſtances as well as poſſible; let the mixture be dried, and reſt for ſome time; extract the colouring matter required, as from cochineal, by means of ſpirit of wine without heat; and let this be poured by degrees upon the calx, rubbing the ingredients well together. When the proceſs is over, the ſpirit ſoon evaporates and leaves the mixture coloured like carmine. If inferior colours only be wanted, the colouring matter may be extracted by water.

There is another method of dying colours from ſubſtances ſimilar to thoſe already ſpoken of; which may ſerve well enough for a coat or ground for more brilliant colours. Theſe are afforded by walnuts and almoſt all aſtringent vegetables. The proceſs is very ſimple. The vegetables are boiled in water, till the colouring matter is extracted: and this being diffuſed through the fluid partly by heat and alſo by the ſolubility of ſome parts of the plants, is kept ſuſpended, ſo long as a certain degree of heat continues: but as the liquid cools, it is precipitated, and in its precipitation is attracted by the cloth, to which it gives a good laſting dye. In this caſe, it ſeems as if the cooling of the liquor produced the ſeparation of the ſoluble and inſoluble, or of the ſoapy and reſinous particles: and ſince the colour is permanent, it follows that the efficacy of mordants muſt in a conſiderable degree be owing to the action of their acids in making a ſeparation of the ſame kind.

Other colouring principles are of ſuch a nature, as to be quite inſoluble in water, but can be diſſolved in alkalies, which convert them into a kind of ſoapy ſtate. Of theſe the principal are thoſe which follow—anotta, from the ſeeds of the bixa, in South America, which yields a fine orange. Alkalies diſſolve it, and render it perfectly ſoluble in boiling water. If wool or ſilk be dyed in the ſolution, they acquire a deep, but not laſting, orange dye ; which is diſcharged by waſhing, and fades by expoſure to the air. It is of uſe to ſteep the ſubſtances dyed with it in a weak acid.—Anotta can be diſſolved in rectified ſpirits of wine, and is uſed as an ingredient in varniſhes, to give an orange caſt to yellows.

Archil is another of this claſs, extracted from a ſort of moſs which grows upon rocks in the Canary and Cape de Verd iſlands.—It is a fine rich purple, but, like the former, of ſhort duration, nor has any method yet been ſtruck out to make it permanent—this likewiſe is employed to give a bloom to other colours. A ſolution of tin is ſaid to change it towards a ſcarlet, and to make the dye of this new colour more laſting than the natural one. The moſt valuable of that claſs, which is inſoluble in water, is *indigo;* it is extracted from the plants and ſtems of the indigo tree ſteeped in water and bruiſed—in ſome time theſe ferment, and the liquid becomes green : it is then decanted off and agitated in large flat veſſels, till blue flocks appear, when lime-water is poured on, and precipitates them. The precipitate is made up into ſmall ſhapes, dried, and ſold under the name of indigo—it is reckoned good if it ſwims upon water, being valued according to its lightneſs.

Pure indigo has but one proper ſolvent, concentrated ſulphuric acid—when ſaturated the ſolution appears black, but being diluted with water it aſſumes a fine blue, called *liquid blue*—this is often uſed to dye wool and ſilk, and the colour has the name of *Saxon blue*. But cotton and linen not having ſo ſtrong an affinity to indigo as wool and ſilk, require a different proceſs, as will be ſeen preſently.—However, all theſe four ſubſtances have ſo ſtrong an affinity for it, as to be capable of being dyed by it without a mordant.

But the common method of dyeing with indigo is not by this ſolution, but by reducing the indigo to a green colour, and then diſſolving it in water, by means of alkalies, which in this ſtate act readily upon it. This may be done by mixing with it ſuch ſubſtances as have a ſtronger affinity to vital air than indigo has; for the blue indigo is but the green ſaturated with this air. Thus indigo is diſſolved, when mixed with pure antimony and pot-aſh. It may alſo be diſſolved by being mixed in water with vegetable ſubſtances which undergo fermentation: during which the indigo loſes its vital air, and may then be diſſolved by means of lime, or alkali, as before. In the dyeing of wool, the vegetable ſubſtances generally employed are, woad and bran—woad of itſelf affords a good laſting blue, and therefore aſſiſts the proceſs in this reſpect. When the ſolution of the ingredients is complete, the liquid appears of a green colour within, but blueiſh toward the ſurface, on account of its contiguity to the air, whoſe vital part it attracts. A ſimilar appearance is made by the cloth, which ſo long as it remains immerſed in the liquid is quite green, but when drawn out ſoon becomes quite blue.—Silk is dyed with ſix parts of indigo, ſix of bran, and one of madder ſtirred together in water, with ſix of common pot-aſh added to them.—This gives but a light blue to the ſilk, which ought to receive another colour previouſly for a ground. Archil is uſually employed for this purpoſe.

Cotton and linen are dyed by one part of indigo, one of green vitriol, and two parts of quick-lime, ſtirred well together in water.—The lime decompoſes the vitriol, ſetting free the green calx, which ſtrongly attracts vital air from the indigo, and thus reduces it to that ſtate in which the lime can diſſolve it. The cloth goes through a ſucceſſion of vats, beginning with thoſe which contain the leaſt colouring matter, and ending with the ſtrongeſt dye. By this method, the cloth is dyed more equally.

The colours already mentioned, are called ſimple: compound colours are thoſe which ariſe from mixing together the ſimple colours.—Thus green is a compound of blue and yellow: it is firſt dyed with one of the ſimple colours, and afterwards with the other. Wool is dyed firſt blue, and then yellow: ſo are cotton and linen: but ſilk is firſt dyed yellow, by means of weld, and then blue—blue mixed with red gives violet, purple, and lilac—yellow with red gives orange, &c.

There are other colouring parts of vegetables, which are ſoluble in oils, as alkanet: this imparts a beautiful red to oily ſubſtances.—Spirits of wine alſo diſſolve others.

It ſhould in general be obſerved, that printed or dyed linens and cottons, ought to reſiſt the action of ſoap: and woollen the action of acids which may accidentally fall on them.

The extractive matter of vegetables abſorbs vital air from the atmoſphere, but much more from dephlogiſticated marine acid, forming a red powder: it alſo is ſoluble, as we have ſeen, in alkalis; and when the ſolution has abſorbed more vital air from the atmoſphere, it forms ſubſtances analogous to reſins.

CHAP. IV.

Of the Acids of Vegetables.

THE acids peculiar to vegetables are, the eſſential, the fermented, and the empyreumatic.—Mineral ſalts are alſo found in vegetables, which are ſuppoſed to enter the veſſels of plants, and to remain there unaltered: but theſe evidently do not belong to them. The eſſential acids are ſuch as are obtained ſimply by preſſure, ſuch as the acids of lemons, ſorrel, &c.: the fermented acids are thoſe, which after undergoing certain proceſſes of fermentation, yield vinegar; and the empyreumatic acids are thoſe, which by dry diſtillation afford a volatile alkali.

The acid of lemons is liable to great changes, from the mucilaginous matter, or pulp, with which it is mixed in its firſt ſtate, after being expreſſed from the fruit.—To preſerve this acid, which is of great value for domeſtic and other purpoſes, various methods have been adopted.—It is, ſometimes, mixed with ſpirits and ſugar, after the pulp has been ſuffered to depoſit and then been removed:

it is preſerved by covering its ſurface with a coat of oil, which anſwers tolerably well, except that the juice loſes its freſh taſte: ſometimes it is evaporated with a gentle heat to a thick conſiſtence, during which the pulp ſeparates, partly ſubſiding, and partly riſing to the ſurface; this muſt be carefully taken away, and the remaining acid preſerved in cloſe bottles.—In this proceſs the acid is concentrated; for no part of it goes off in vapour. Another method, and the moſt approved, for preſerving lemon acid, is by freezing—it is ſuffered to depoſit the pulp for ſome time, then carefully decanted and filtred off: and this may be repeated—it is then expoſed to cold, ſeven or eight degrees below the freezing point: and the ice continued to be removed, till it begins to get an acid taſte: the remaining acid is concentrated to ſeven or eight times its firſt ſtrength, and may be preſerved, if well cloſed up in this ſtate, or made into a dry lemonade, by adding about ſix times its weight of loaf ſugar.

For chemical purpoſes more accuracy is neceſſary in obtaining the pure acid. For this purpoſe, the lemon juice, in a boiling ſtate, is to be ſaturated with powdered chalk: a powder, conſiſting of the acid joined to lime, falls to the bottom, which muſt be well waſhed with warm water.—Diluted ſulphuric acid is then gradually poured on this powder, which uniting with the lime will form a precipitate, leaving the lemon acid diſſolved in the fluid—this ſolution is then evaporated to the conſiſtence of a thin ſyrup: and a ſmall portion of ſulphuric acid again added, till no lime be ſuffered to remain: after which the acid of lemons cryſtallizes by evaporation. This acid is ſometimes called *citric acid*, as being obtained from citrons; and may alſo be had from ſtraw. It is ſeldom found in an uncombined ſtate, but mixed with others.—Acid of lemons is of extenſive uſe in cookery and medicine, &c. and is ſometimes employed to take out ſtains from cloths.

Acid of apples, called *malic acid*, is another of thoſe which are obtained by preſſure.—The ſame acid abounds alſo in other ſour fruits.—It is purified by firſt ſaturating it with vegetable alkali: and then by gradually adding a ſolution of lead in vitriolic acid—a double elective attraction takes place: the vitriolic acid combining with the vegetable alkali, and forming vitriolated tartar; while the acid of apples unites with the lead, forming an inſoluble precipitate: to complete which, a little ſugar of lead, in a ſtate of ſolution, is added. The vitriolated tartar being ſoluble, is waſhed off from the inſoluble precipitate: and to this is added diluted vitriolic acid, which ſeparates the lead, leaving the acid of apples free.—This acid cannot be cryſtallized, but always remains in a liquid ſtate: or, if much evaporated, attracts moiſture from the atmoſphere.—It precipitates ſilver, lead, and quickſilver, from their ſolutions in nitrous acid, and alſo gold from its ſolution, when diluted.—It is converted into acid of ſugar, by diſtilling nitrous acid from it. Malic acid is found generally uncombined.

There are ſome fruits, ſuch as gooſeberries, which contain in them both the acid of lemons, and acid of apples.—Theſe are ſeparated in the following manner—the juice is evaporated to the conſiſtence of ſyrup: then ardent ſpirits is added, which attracting the acids, ſets free the pulp.—This being removed by filtration, and the ardent ſpirit afterwards driven off by evaporation, the acids are ſaturated with chalk.—When the ſolution has been boiled for a few minutes, the acid of lemons, with its chalk, falls to the bottom, while the acid of apples, a more powerful ſolvent, holds its chalk ſuſpended, and may with it be decanted off.—The ſalt of lemons may then be ſeparated from its baſe of chalk by vitriolic acid: while the other ſalt of apples may be treated with ſugar of lead nearly as before.

It has been generally ſuppoſed, that certain vegetables, poſſeſſing an aſtringent property, owe to this their power of precipitating metals from their ſolution. But, probably, theſe effects are rather owing to an acid, which is found in them. The principal of theſe is the nut-gall, which is one of the chief ingredients of ink, on account of its great power of precipitating iron from a ſolution of vitriol, as was mentioned on a former occaſion.—Ink is beſt made by infuſing one part of martial vitriol, one of powdered logwood, and three of powdered galls, in one quart of white wine, or water, allowing for each quart an ounce of vitriol, and an ounce of gum Arabic—the mixture muſt be ſhaken ſeveral times each day, during ten or twelve days, and then decanted for uſe. Vinegar is not ſo good as wine or water, for it ſoon corrodes and blunts the writing pen.—Ink grows black by expoſure to air; probably from the acid becoming ſtronger by attracting vital air.—This acid may be ſeparated from the other matters of the galls, by adding fixed alkali to a decoction of them: for this ſets free the aſtringent matter, and unites itſelf to the acid.—Or it may be obtained by diſtillation of the galls, in which proceſs an acid liquor firſt comes over, and afterwards a volatile ſalt, which is the true acid. It may alſo be procured by cryſtallization, if an infuſion of them be made with cold water, and expoſed for a long time to the action of the air, removing conſtantly the ſcum from the ſurface: the ſediment, at laſt, by filtring and evaporating, forms into cryſtals.

This acid unites with lime, magneſia, and ponderous earth, forming with them ſoluble ſalts—it reddens blue paper, decompoſes moſt of the metallic ſolutions, and combines with their calces.

Acid of benzoin is another vegetable acid, contained in a reſin, which flows from a tree in Sumatra.—The bark is cut, and the flowing ſubſtance concretes by expoſure to air, when it is ſcraped off with a knife. What iſſues firſt from the tree is white, ſoft, and fragrant, and is reckoned pureſt: that which comes after is brown, and is leſs eſteemed.

If this reſinous ſubſtance be diſtiiled with a gentle heat, it ſublimes into a fine ſaline matter, of a fragrant ſmell, and ſlightly acid taſte, called *flowers of benzoin*, which are much uſed in medicine. But the acid is beſt obtained in the humid way, by mixing about nine pounds of lime water with one of benzoin in powder; which is to be done by firſt pouring on but a few ounces of the lime water, and by agitating the maſs continually, both now and after the reſt of the water is added, and expoſed to a gentle heat. When the liquor is cool, it is decanted; and this proceſs twice repeated with the reſidue.—All the waters are then evaporated to two pounds, during which a ſmall quantity of reſin falls down.—After this, a little marine acid is added, drop by drop, till no more precipitation takes place.—The precipitate is acid of benzoin.

In this proceſs, the lime and acid of benzoin have been united by heat: the evaporation diminiſhes the water, and in ſo doing, firſt lets fall a ſmall quantity of reſin, and afterwards the acid of benzoin.—Then the marine acid takes up the lime, ſetting the remainder of the acid of benzoin free: which, being rather inſoluble, ſinks to the bottom.

Acid of tartar is the acid of that ſalt, which during fermentation is thrown off from wine, and depoſited upon the ſides of the wine caſks: and is of a whitiſh or red colour, according to the colour of the wines.—This ſalt, however, is not the effect of fermentation, for it is found ready formed in the juice of the grape, tamarinds, and other fruits, and in verjuice.

Tartar, when burnt, yields an alkali, which is called ſalt of tartar. Cream of tartar on the other hand is an acid (at leaſt for the moſt part) and is obtained by diſſolving the tartar in boiling water, and afterwards by filtring and evaporation. When the cryſtals ſo obtained are boiled with clay or whites of eggs to raiſe the impurities, and the ſcum has been removed, a light ſkin or covering of ſalt begins to appear on the ſurface, while cryſtals are formed at the bottom. Theſe are both blended together, and are either called from the former *cream of tartar*, or *cryſtals of tartar* from the latter.

If the ſolution of this ſalt be expoſed to the air, a ſoft gummy ſubſtance is depoſited, the acid diſappears, and at the end of about eighteen months the liquid is found to contain vegetable alkali, equal in weight to what would have been obtained from burning the tartar. Whatever be the cauſe of this change, it proves that the vegetable alkali is not the product of fire.

Cream of tartar was formerly ſuppoſed to be an acid mixed with earthy impurities; but is now ſhewn to be a compound ſalt, containing an alkali joined to an acid, but in which the acid is predominant. And accordingly if the ſalt be diſſolved in boiling water, and powdered chalk be added, till efferveſcence ceaſes, a precipitation takes place, and the remaining liquor being evaporated yields what is called *ſoluble tartar*; the very ſame ſalt which ariſes from combining vegetable alkali to ſaturation with cream of tartar. The precipitate conſiſts of the chalk united to the exceſs of the acid. Cream of tartar, boiled in four or five times its weight of water, and ſaturated with foſſile or mineral alkali, affords, by filtring and evaporating, a ſalt called Rochelle ſalt, or ſal de Seignette, from the name of its diſcoverer. at Rochelle. It is a gentle purgative, and leſs nauſeous than moſt others.

Cream of tartar, combined in equal quantity with glaſs of antimony, produces the powerful medicine called *tartar emetic*, as we have had occaſion to mention before. The pure acid of tartar may be obtained by boiling cream of tartar in five or ſix times its weight of water, then adding by little and little ſtrong vitriolic acid till all precipitation ceaſes. Vitriolated tartar will be precipitated, and the remaining liquor being filtred and evaporated to the conſiſtence of a ſyrup will yield cryſtals.

The acid of tartar is uſed in the arts: cream of tartar combined with antimony, iron &c. &c. is uſed in medicine &c.

Acid of ſugar is obtained by frequent diſtillations of fine powdered ſugar with about three times its weight of ſtrong nitrous acid. It has great power; a few grains of it giving an acid taſte to a pint of water; and one part of it ſaturating ſix parts of volatile alkali. It acts upon all metals, if they have been previouſly diſſolved in an acid, and afterwards precipitated. Iron in the metallic ſtate is largely diſſolved by acid of ſugar. This acid is thought to be the ſame with the acid of ſorrel, which is obtained from the oxalis or wood ſorrel.

Beſide theſe, are many other vegetable acids or ſalts, which may be diſcovered by fire, or by the nitrous acid; as acid of camphor, cork, &c. &c.: but theſe have not yet been applied to ſo uſeful purpoſes as the foregoing. It ſhould be obſerved, that ſome ſubſtances contain ſeveral of thoſe vegetable acids, or at leaſt more than one: that all theſe acids conſiſt of charcoal and inflammable gas; and that they are convertible into each other by means of the nitrous acid.

CHAP. V.

Of Fermentation; and firſt of Vinous Fermentation.

AFTER having conſidered the principles of vegetables which are diſcovered either by ſimple expreſſion, or by the action of fire, we ſhall now conſider the changes they undergo by fermentation.

Fermentation is a ſpontaneous motion which is excited in vegetables and other organized ſubſtances, and which totally changes their properties. To carry on this proceſs the general requiſites are, 1ſt, that the ſubſtances be in ſome meaſure fluid; 2ndly, that there be heat in a greater or leſs degree; 3rdly, that there be acceſs of air. Bodies quite dry will not undergo fermentation; neither will they in very intenſe cold; nor in a ſpace void of air. Air is probably a great ſolvent of many component parts of bodies: and without heat and moiſture very few, if any chemical proceſſes take place: and fermentation is a natural proceſs of this kind.

There are three principal kinds of fermentation. 1ſt, the vinous or ſpirituous which produce wine or ſpirits: 2ndly, the acetous, the product of which is vinegar: 3rdly, the putrid, which produces volatile alkali. Theſe are thought by ſome writers to follow in the conſtant order here laid down. But this is queſtioned by others, who contend that the laſt ſometimes takes place without any appearance of the former two. It ſhould be obſerved alſo, that vinegar can be produced by other chemical means beſide fermentation. In the vinous or ſpirituous fermentation, beſide the general conditions juſt mentioned, the ſubſtances muſt contain ſaccharine juices, and mucilage, and ought to be in large maſſes ſufficient to excite a conſiderable degree of motion. When theſe conditions take place, the fermentation goes on; attended with an increaſe of bulk in the mixture, a turbid or troubled appearance, a riſing of ſome parts of the mixture to the ſurface in a kind of yeaſt or froth, and a diſcharge of aerial acid in the form of bubbles. As the liquor becomes briſk and heady, theſe appearances ceaſe. In the above proceſs mucilage abſorbs vital air, and thus probably contributes to the fermentation.

The beſt of all fermented liquors is wine, the juice preſſed from the grape. The grapes are put into a veſſel, expoſed to a heat of about 47° of Farenheit, bruiſed, trampled, and much agitated: after which the fermentation is excited, and the appearance abovementioned take place.

When the wine is made, it is let out below into open barrels: where it undergoes a ſecond, though inſenſible, fermentation, which more intimately combines its principles. In this proceſs a fine ley and tartar are precipitated upon the ſides of the veſſels.

Wines greatly differ from each other, on account of the quality of the grape, the climate, ſoil, and other natural cauſes; as likewiſe from the different managements in the proceſs of making. If the fruit be unripe, the wine will abound with an acid, and have a thin ſharp taſte: if the fruit be ripe, the wine will be more ſweet and mellow. Caſking it up in an earlier or later ſtage of fermentation has alſo a ſenſible effect upon the flavour, the wine having in the former caſe a ſtronger taſte of ſugar, which has not had time to be decompoſed. If the fermentation has been checked by too great cold, the wine wants that briſk and lively taſte, which ariſes from the eſcape of fixed air during the fermentation. By proceſſes ſimilar to this, cyder and perry are made from the juices of apples and pears. Beer is extracted from barley in the following manner. Barley is firſt reduced to malt by being ſteeped in water about two days to ſoften it. The water being then drained off, the barley is laid thick upon a floor, where it begins to ſhoot and grow, and ſo to unfold the ſaccharine juices. As ſoon as this appearance takes place, it is then ſpread thinner, and turned over twice a day for two days: after which it is made into a heap, and ſuffered to become ſenſibly hot; then it is taken to the kiln, and dried into malt. The malt, being ground, is put into a large veſſel, and hot water under the degree of boiling, poured on; and the whole is ſtirred about to extract the juice. When this operation, called maſhing, is over, the liquor is ſuffered to ſtand for ſome time, and is then drawn off at the bottom: this makes the ſtrongeſt beer. Another decoction is made weaker than the former, and both are either mixed or kept ſeparate. They are then boiled with hops, which gives a pleaſant bitter aromatic taſte to the beer, and renders it leſs liable to be ſpoiled in keeping: afterwards it is cooled in ſhallow veſſels, where it is allowed to ferment with the addition of barm.

It is evident that the quality of the beer muſt depend not only on the quality and proportions of the materials, but alſo on the careful management of the whole proceſs. In breweries, where great nicety is obſerved, the thermometer is conſtantly uſed to regulate the temperature of the fluids.

Meath and metheglin are the product of fermented honey, and rum of the ſugar cane, or of ſugar diſſolved in water, after it undergoes fermentation.

The products of all this kind of fermentation are liquors, more or leſs coloured, of an aromatic ſmell, a hot and pungent taſte; which, taken in ſmall quantities, animate the weakened fibres, and exhilarate the ſpirits, but taken in large quantities, relax and enfeeble the powers both of body and mind. They are compounds of different ſubſtances; grape wine for inſtance is a compound of water, ardent ſpirit, ſalt of tartar, and a certain extract, to which red wines owe their colours. It is from the circumſtance of ardent ſpirit making a part in wine, and every other product of the firſt kind of fermentation, that this is called ſpirituous as well as vinous fermentation.

CHAP. VI.

Of Spirit of Wine and Ether.

THE product of the vinous fermentation contains an ardent ſpirit, which is to be obtained pure by repeated diſtillations.—If wine be diſtilled in a boiling ſtate, a fluid comes over into the receiver, of a whitiſh colour, a pungent hot taſte, and a ſtrong ſweet ſmell; it is called *aquavitæ.*—The ſpirit is here more concentrated than before: but this fluid ſtill conſiſts of water, ardent ſpirit, and a ſmall quantity of oil, which gives it in ſome time a yellow colour:—and this colour is further deepened by age, the aqua vitæ imbibing the extractive matter of the caſks which contain it.

It ſhould be obſerved, that after wine has been decompoſed by thus diſtilling it, it's former properties cannot be reſtored again by ſyntheſis, viz. by combining the ſpirituous product with the reſidue.—The analyſis, therefore, cannot be ſimple; but ſome change has taken place in theſe properties by the operation.

If aqua vitæ thus obtained, be diſtilled a ſufficient number of times, it will be rectified from the water and oil: in which ſtate it is called ſpirit of wine.—An eaſy method to reduce the water is, by mixing pot-aſh, and decanting the ſpirit.

Spirit of wine is a clear, light, and volatile fluid, of a hot ſharp taſte, and an agreeable ſmell.—When burnt it air, it preſents a ſlight flame, blue at the edges, and white in the middle.—If it be expoſed to the air, it evaporates at ſo low a temperature as ten degrees above the freezing point, and leaves no reſiduum except a little water.—It has never been frozen.

Spirit of wine very readily diſſolves in water: and the ſolution is attended with heat: the combination is ſo ſtrong, that ſpirit of wine precipitates from water all the ſalts diſſolved in it: and this, in turn, ſeparates from ſpirit of wine many ſubſtances combined with it.

It combines well with fixed alkali, and forms with it *acrid tincture of tartar:* and if the fixed alkali be cauſtic, by being deprived of its fixed air, it gives *lily of Paracelſus;* both, medicines of great uſe in fevers, and other complaints, where the ſtrength of the patient is too low to favour a criſis.

All the acids combine with ſpirit of wine, in different degrees: the three principal acids, united with it, form ethers.

Vitriolic ether is obtained, by pouring very concentrated vitriolic acid, upon an equal quantity of rectified ſpirit of wine.—This mixture is attended with heat and an hiſſing noiſe, emits a fragrant ſmell, and becomes coloured : and if diſtilled in a ſand bath, it yields ſeveral products, among which are ſpirit of wine, ether which has a ſweet ſmell, and is extremely volatile, and a ſulphureous acid. The vitriolic ether thus obtained, is impure, being mixed with ſpirit of wine and ſulphureous acid.—It is rectified by diſtilling it in a ſand bath, with cauſtic fixed alkali, which combines with the acid, and ſuffers the ether to paſs over in a much purer ſtate.

Vitriolic ether is much more eaſily obtained, than either the nitrous, or marine : than marine, becauſe the affinity between this acid and ſpirit of wine is very ſlight : and than nitrous, becauſe the combination of nitrous acid and ſpirit of wine is ſo extremely rapid, that the veſſels, in which they are mixed, frequently burſt by the diſengaged air. Various methods have been taken for procuring nitrous ether : among theſe, one diſcovered by Dr. Black, ſeems very ſimple and well contrived—he put two ounces of ſtrong nitrous acid into a phial : he then poured in very ſlowly about an equal quantity of water, which run down the ſides of the phial in gentle ſtreams, till it covered the ſurface of the acid, on which it ſwam being lighter. In the ſame manner, about three ounces of rectified ſpirit of wine was gently poured on the ſurſace of the water, on which it ſwam: ſo that a layer of water was now interpoſed between the acid and ſpirit. By degrees the acid riſes by attraction to the ſpirit, through the water, and mixing with it, forms very pure nitrous ether, without producing elaſtic vapours.

Ether is a much lighter fluid than ſpirit of wine, of a ſtrong ſmell, and hot taſte; extremely volatile, ſo as to be diſſipated the inſtant it is poured out: and it's evaporation produces ſo great a degree of cold, as to congeal water. It kindles with the electric ſpark, or in contact with any body on fire in the open air: it ſends forth a very bright luminous flame, which leaves a mark upon the ſurface of any body expoſed to it.

Ether is employed in medicine, as a powerful tonic or bracer, and alſo in caſes of ſpaſms; but ought to be adminiſtered with great caution.

Spirit of wine unites with ſulphur, when both ſubſtances are in a ſtate of vapour.—It has no action upon metals, or their calces: it diſſolves in part ſuch bitumens, as are not black and charry: it acts but ſlightly upon the neutral ſalts, but rather more ſtrongly on thoſe which poſſeſs vitriolic, than thoſe which contain nitrous or marine acids.—Moſt vegetable ſubſtances unite with ſpirit of wine, and in this union the extracts loſe their colouring part, which combines with the ſpirit. But its chief combinations are with oils, camphor, reſins, and balſams: with which it forms elixirs, tinctures, and other mixtures.——Theſe medicines are prepared by drying the plant, whoſe eſſential oil, or reſin, is to be diſſolved, and then expoſing it to the action of the ſpirit of wine upon a ſand bath, with a gentle heat, and by agitation.

Spirit of wine, and aqua vitæ, are of extenſive uſe: the latter is uſed to ſupport oppreſſed ſpirits, but is dangerous when taken to exceſs: the former, beſide its important ſervice in medicine, is alſo uſeful in ſeveral arts, painting, dyeing, and others.—If mixed with oil of ſpike and turpentine, it compoſes fine dry varniſhes.

CHAP. VII.

Of acetous Fermentation, and of Vinegar.

THE ſecond kind of fermentation is the acetous, by which vinegar is produced, from wine, cyder, beer, and other liquors. This fermentation is ſuppoſed to be owing to thoſe liquors attracting and abſorbing vital air from the atmoſphere: which theory is confirmed by theſe facts—firſt, that wine cannot be changed into vinegar without the contact of air containing vital air; ſecondly, that it is attended with a diminution in quantity of ſuch air; and thirdly, if wine be impregnated with this air, in any other manner, vinegar will be the reſult.

The moſt uſual method of making vinegar is, by means of two veſſels, each containing ſome refuſe of grapes, and ſuch matters: one of theſe is filled with wine, the other is half-filled—in this latter the fermentation firſt begins, at which time it muſt be checked by filling this veſſel out of the other. Soon after, the fermentation takes place in this, at which time it is to be re-filled in turn: and ſo the proceſs goes on alternately, for about fifteen days, when the vinegar is made.

It may alſo be prepated from water, containing raiſins or ſugar, about three pounds to the gallon, expoſing it for ſome months to a hot ſummer ſun, and occaſionally affording acceſs of air.—The veſſel employed for this purpoſe ought to be ſtrong and iron-hooped, to prevent its burſting.

The moſt proper matters for producing this fermentation are, in general, the fæces or dregs of acid wines, eſpecially Rheniſh, the lees of vinegar, tartar pulveriſed, yeaſt, leaven, and all manner of ferments.

Vinegar is purified by diſtillation.—The firſt portion which comes over is a watery fluid, ſcarce acid: next comes the acetous acid, commonly called diſtilled vinegar: after this, portions ſtill more acid; and at laſt the reſidue, which is of a reddiſh brown colour, is conſiderably acid, and depoſites tartar.

Vinegar may be concentrated by froſt, which freezes the water without affecting the acid.

The acetous acid enters into various combinations.—With argillaceous and calcareous earths, and with magneſia, it forms different ſalts.—With vegetable alkali, it produces a ſalt, ſometimes called *foliated earth of tartar*. If two parts of this ſalt be diſtilled with one of vitriolic acid, the acetous acid is ſoon diſengaged, and riſes in the elaſtic form.—When condenſed in the receiver, this fluid is called *radical vinegar*, whoſe acid properties are much ſtronger than thoſe of the common acetous acid.—With mineral alkali it forms a ſalt nearly of the ſame nature, but affording a ſtill ſtronger acid.—With volatile alkali vinegar gives a ſalt called *ſpirit of mindererus*, which does not eaſily cryſtallize, but requires to be evaporated to the conſiſtence of a ſyrup, and then expoſed to the cold—it has a ſharp and burning taſte; and is uſed as a medicine in fevers.

The acetous acid has little or no effect upon gold, ſilver, or mercury, in their metallic ſtate, though it acts ſenſibly upon their calces.—It combines eaſily with lead; as appears from the manufacture of ceruſe and ſugar of lead already mentioned.—It diſſolves copper, if atmoſpheric air be preſent: the cryſtals of this laſt ſalt are ſometimes called diſtilled verdigriſe.—Iron and tin are likewiſe diſſolved by it.—Common vinegar, and iron filings, have but a ſlight action on each other, unleſs they ſtand for ſome time: during which, probably the action of the air may aſſiſt their combination, and the water of the vinegar may be decompoſed.

The acetous acid likewiſe acts upon the ſemimetals in different ways; on ſome, in both the metallic and calcined ſtates; on others, only in the latter—but what is moſt important to be known upon this ſubject is, that zinc is ſoluble in both ſtates; and is, therefore, very unfit to make part of any compoſition for defending copper veſſels from vinegar.

The third kind of fermentation, called putrid fermentation, though it takes place in vegetables containing their juices, and expoſed to a moiſt air, yet as it exhibits a more ſtriking appearance in the animal kingdom, ſhall be treated under that head.

SECT. V.

Of Animal Subſtances.

CHAP. I.

Of Animal Subſtances derived from Natural Secretion.

MILK is a fluid of a whitiſh colour, and of a mild, ſoft, and pleaſant taſte: it is ſecreted in peculiar veſſels of certain female animals for the ſupport and nouriſhment of their young. When viewed with a microſcope, it has the appearance of ſmall opake globules, like thoſe of blood, floating in a tranſparent fluid.

By deſtructive diſtillation, which may be done by expoſure to the heat of a reverberatory furnace, milk affords an acid, oils, and volatile alkali. Its reſidue contains vegetable alkali, the ſame alkali alſo united with the marine acid, and a phoſphoric ſalt with baſe of lime.

Milk is capable of paſſing through the three ſtages of fermentation: and although the vinous continues but a ſhort time, yet that it undergoes this, is evident from a kind of wine, called *Koumiſs*, made from mare's milk by the Tartars. If milk be ſuffered to ſtand for ſome time, it forms itſelf into two ſubſtances, one of which the thicker and lighter, floats upon the ſuface of the other, and is called *Cream.* It is moſt ſpeedily ſeparated, when moſt expoſed to air, whoſe vital part it abſorbs. By agitation in the churn it affords butter: when freſh, it requires a longer time to compleat this proceſs, than when long expoſed to air. It is thought by ſome that butter is formed by mere mechanical means, the fatter particles being brought into contact with each other by the agitation, and adhering together ſo as to make up the ſolid maſs. By others the proceſs is ſuppoſed to be chemical, and the vital part of air to have a conſiderable ſhare in it. Butter ſeems to reſemble fat oils it its properties: and when decompoſed yields ſimilar products.

The thinner fluid, into which milk reſolves itſelf, becomes ſour and is ſeparated into two parts; a ſolid ſubſtance called *curd*, and a fluid *whey*: this laſt contains the acid of milk. A ſimilar change takes place by the addition of acids to milk, eſpecially if aſſiſted by heat: as alſo by ſugar and gum arabic. But the moſt remarkable and uſeful of all coagulations of milk is produced by the addition of *rennet*, which is the infuſion of a young calf's ſtomach in water. It is by means of this that *cheeſe* is manufactured, which is done as follows. As ſoon as the milk is turned, the whey is carefully ſtrained from the curd. The curd is then broken ſmall, and put by little and little into the vat, or mould for making the cheeſe pierced with holes in the bottom to let the whey paſs freely off. A clean cloth is placed within, ſo large as to cover all the curd, and the vat is filled an inch or more above the brim: the cloth is then drawn over the curd, which is taken to the preſs, and remains for the ſpace of two hours: afterwards it is turned, a freſh cloth applied, and preſſed again for ſix or eight hours. This operation is again repeated, and the third preſſing continues fourteen or fifteen hours. It is then placed on a dry board, and regularly turned every day.

Cheeſe, when decompoſed by deſtructive diſtillation, affords an alkaline phlegm, an oil, and volatile alkali. Its reſidue treated with nitrous acid is found to contain lime and phoſphoric acid.

Cheeſe is not ſoluble in water, but is hardened if the water be hot. By this property it is capable, when mixed with lime, of making an excellent cement for wood, ſtone, earthen ware, and glaſs. The cheeſe is ſhaved thin, and ſtirred with boiling water ſeveral times: the ſlime which is thus formed is mixed upon a hot ſtone with quick-lime into the conſiſtence of a paſte.

Acid of Milk is obtained by evaporating ſour whey, till only one eighth part of it remains, by adding lime water which precipitates the animal earth; diluting the remaining fluid with three times its quantity of water; and adding the acid of ſugar to purify it from any redundant lime. This purified liquor is then evaporated to the conſiſtence of honey, and ardent ſpirit added, which takes up the acid of milk, leaving behind all the foreign ſubſtances. Laſtly this ſolution of the acid in the ardent ſpirit is diluted with water, and the ſpirit ſeparated by diſtillation: the acid remaining in the retort.

If this acid be decompoſed by deſtructive diſtillation, it affords water firſt, then a weak acid, next an oil with more of the ſame acid: fixed air, and heavy inflammable air.

The acid of milk cannot of itſelf be converted into vinegar, from the want of ſuch ſubſtances as during fermentation produce ſpirits; that this is the true cauſe appears from hence, that if to a veſſel of milk be added a very ſmall portion of brandy, occaſionally allowing vent to the air, the whey, in the courſe of a month becomes good vinegar.

This acid combines with all the alkalies, and earths, forming with them different ſalts. It diſſolves iron, zinc, copper and lead: but has no effect upon gold, ſilver, tin, mercury, biſmuth, cobalt, antimony.

Sugar of Milk is that ſubſtance, upon which its fermenting property depends. It is obtained by evaporation of the whey to the conſiſtence of honey, then run into moulds, and dried in the ſun; and is uſed in the preparation of medicines. It yields the ſame kind of products which other ſugars do. The ſugar of milk contains an acid which may be had by diſtilling its fine powder in a ſand bath with about three times its weight of diluted nitrous acid. The mixture ſoon grows hot and diſengages nitrous air, and aerial acid. The retort is then taken off, and the mixture ſuffered to cool, after which the remainder of the nitrous acid was diſtilled off till the maſs acquired a yellowiſh colour. More nitrous acid (about two thirds of the former quantity) was added, and the mixture again diſtilled. When cool, it was found to be thick, and being diſſolved in water was filtred. The ſolution which paſſed through the filter was evaporated tô the conſiſtence of a ſyrup, a little more nitrous acid added, and the evaporation repeated in a ſand heat. When the whole was cool, acid cryſtals were formed. This acid unites with the ſoluble earths forming inſoluble ſalts; with the fixed alkalies it forms neutral ſalts; and with the volatile, a ſalt, which has a ſour taſte. It has no ſenſible effect upon the metals, but acts upon their calces.

Eggs contain two ſubſtances, the white and the yolk. The *white* is a colourleſs liquid, which does not ſeem to differ much in its properties from milk or cheeſe. It coagulates with heat, acids, and ſpirit of wine, into a white ſolid maſs, having the ſame weight and bulk which it had in the fluid ſtate. Yet its appearance and properties are changed; and it is not ſoluble in water as before. If the liquid white of eggs be diluted to a certain degree with water, it will no longer coagulate with heat, and if further diluted, not even with acids or ſpirit of wine. But if concentrated again by evaporation, it coagulates as before it was diluted. The coagulated white is diſſolved by mineral acids, conſiderably diluted with water: and if a concentrated acid be added, it is again precipitated. Pure alkalies and lime water alſo diſſolve it.

The *yolk* of eggs is a yellow oily matter, which is capable of being diffuſed in water. The oil, which it contains, may be ſeparated by drying and afterwards preſſing it.

Honey and wax are ſubſtances prepared by the bee, and for this reaſon are ranged among the animal ſubſtances; although they may be vegetable matters collected from plants, and brought home in veſſels appointed for the purpoſe, the former being contained in a bag within the body, the latter in cavities on the thighs of the bee. Honey is of a yellowiſh white colour, ſoft, ſweet, and aromatic; and yields by means of ſpirit of wine, or even water with proper managemement, a true ſugar. It is ſoluble in water, and goes through all the different kinds of fermentation. By diſtillation it affords an acid phlegm, and an oil: its reſidue being a light ſpongy coal.

Wax is a ſubſtance, which reſembles the more ſolid fixed oils. Bee's wax is of a yellow colour, and becomes white by expoſure to air. But as this power of the air does not reach beyond the ſurface various methods are employed to expoſe different ſurfaces. One of the beſt ſeems to be to pour the wax in a melting ſtate upon a cylinder lying horizontally, and half immerſed in water, and by turning this round its axis. By theſe means thin layers of wax are made one over the other, which may be eaſily ſeparated, and expoſed to the air. It is by the vital part of air that wax is whitened, as is manifeſt from the powerful effect produced in bleaching it by dephlogiſticated marine acid, which abounds in this. Candles are made of wax, and have this advantage among others over thoſe made of tallow, that a much thinner wick anſwers the purpoſe in the former than in the latter. The reaſon is, that wax is not fuſible by heat as tallow; and unleſs there be a wick of conſiderable ſize to volatilize the tallow in fuſion, it runs over, and down the ſides of the candle. The incoveniences of a thick wick are not only, that it prevents the acceſs of air to the middle of the flame, but alſo is a ſupport to the wick as it lengthens, and renders conſtant ſnuffing neceſſary; whereas the thin wick of the wax candle ſoon bends out of the flame and is reduced to aſhes.

Lac, called ſtick-lac, ſhell-lac, and ſeed-lac, is the product of an inſect which lays its eggs on the branches of a tree called bihar in the eaſt: it ſeems deſigned to anſwer the purpoſes of defending the eggs, and feeding the inſect. It is purified by being broken into ſmall pieces, and held over the fire in a canvaſs bag, till the lac is liquid enough to paſs through: when it is taken off the fire, twiſted in different directions, and drawn along the convex part of a plantain tree.

Lac makes a hard varniſh, by being combined with ardent ſpirit, and digeſted in a moderate heat. The chief uſes of it are however in dyeing and in the manufacture of ſealing wax; which is a compoſition of gum lac with reſin and vermilion made into a powder, melted, and formed into ſticks. In dyeing we have already ſeen its uſe.

Urine is one of thoſe ſubſtances, which are rejected out of the bodies of animals, as uſeleſs. We have already ſeen, that phoſphorus is extracted from it; and that the acid, which it contains, is the phoſphoric, is evident from pouring lime water into it, for a powder precipitates which is a combination of this acid with lime.

The brick coloured precipitate let fall upon the cooling of freſh urine is found to be an acid called the *uric acid.* This is very various according to the different ſtates of health. In fevers of the intermitting kind it is copious, and makes its appearance at the criſis. In gouty habits it appears in abundance towards the end of a fit. And if it ſuddenly diſappears, a freſh attack may be expected. Urine contains alſo a kind of jelly, which, though ſmall in healthy caſes, yet in others eſpecially dropſical is very conſiderable, ſo that the urine coagulates with acids or even heat. It alſo is found to contain ſeveral other matters, as marine acid in combination with mineral and volatile alkalies, &c. &c. The urinary calculus, commonly called the ſtone in the bladder has been examined with all the attention due to ſo dreadful a cauſe of diſeaſe. It is found to be different in ſubſtance in different caſes. The greateſt number conſiſt chiefly of the uric acid abovementioned. Theſe may be diſſolved, by injecting into the bladder ſolutions of alkalies, not ſo ſtrong as to hurt the bladder. The gritty ſubſtance called gravel indicates the calculus to be of this kind. Others conſiſt of phoſphoric acid united to lime, and alſo to magneſia and volatile alkali. In theſe caſes relief may be obtained by injecting marine acid ſo weak as hardly to have an acid taſte.

Ambergris is generally ſuppoſed to be a ſubſtance voided by the ſpermaceti whale. It is found in the ſea, near the ſhores of various tropical countries; and is of various colours. A ſlight warmth ſoftens it like pitch: it has a fragrant ſmell when heated; and melts like reſin. Oils diſſolve it, and ſo do ardent ſpirits. It does not ſeem to be perfectly aſcertained whether there may not be alſo a vegetable ſubſtance reſembling this in properties.

Ambergris was formerly uſed as a medicine, and is ſtill applied to this purpoſe in the eaſt, but in theſe countries it is chiefly employed in perfumery.

CHAP. II.

Of Animal Subſtances contained within the Syſtem.

OF the ſubſtances contained within the ſyſtem, one of the moſt obvious and important to be noticed is, the blood, which keeps conſtantly circulating, and which ceaſing to flow, life ſoon ceaſes likewiſe.

The blood, when quite freſh from the veins or arteries, appears to the naked eye of an uniform red colour: but if viewed with a microſcope, exhibits a great number of red globules ſwimming in a tranſparent fluid, to which the red colour of the blood is owing.—When blood remains for ſome time at reſt, it coagulates into a ſolid maſs; and this gradually ſeparates into two different matters, one of which is fluid, called the *ſerum*; the other a thick red matter, called the *craſſamentum*, or the *cruor:* this laſt generally ſinks down, and is covered by the ſerum.—If the craſſamentum be waſhed with water in ſufficient quantity, it loſes its red colour, and is changed into a white ſubſtance, which has a fibrous appearance: and if the blood be received from the vein in warm water, it depoſites the ſame kind of matter.

Diſeaſed appears different from healthy blood: for inſtance, in caſes of inflammation, the red globules ſink to the bottom, and the fibrous matter appears at the top, of its natural whitiſh colour: and hence the appearance of that buffy coat, which characterizes blood during inflammation. This is owing to the blood not coagulating ſo ſoon as in health, and time being thus given for the red globules to ſubſide.

Acids promote the coagulation of blood, and form with part of it a neutral ſalt, ſimilar to that formed by the union of their acids with mineral alkali; whence it is plain that blood contains this alkali.—Ardent ſpirit alſo coagulates it, but alkalies do not.—By deſtructive diſtillation blood yields a watery liquor holding a neutral ſalt in ſolution, next a light oil, a denſer oil, and volatile alkali—the reſidue is a coal containing common ſalt, mineral alkali, and an earth.

The *ſerum* is of a light green colour, and contains an alkali: for it changes ſyrup of violets to a green—it reſembles in many reſpects the white of eggs: like that it coagulates with heat, and alſo with acids and ardent ſpirits:—by diſtillation it yields phlegm, mild volatile alkali, and a thick oil: the reſidue affords mild mineral alkali.

The *craſſamentum* by diſtillation becomes dry and brittle, and emits an alkaline phlegm, then an oil, and concrete volatile alkali: the reſidue is found to contain mineral alkali and iron.

The proportion of ſerum to craſſamentum is not the ſame in all caſes: the moſt general proportion is thought to be about three to one.

If freſh blood be ſtirred round briſkly with a ſtick, the fibrous matter is ſeparated, and adheres to the ſtick, while the red globules remain behind, and mix with the ſcum.—It is in this manner that blood is prepared for clarifying ſugar, &c. &c.

The ſoft and flexible parts of animals, called cartilages, tendons, ligaments, and membranes, differ greatly from the muſcular parts: and when boiled in water, yield the ſubſtance known by the names of glue or jelly.—It is ſoluble in water, either hot or cold, and is diſſolved by alkalis and acids.—By deſtructive diſtillation it affords the ſame products as the ſerum of blood: the reſidue is common ſalt, with the phoſphoric ſalt of lime.

It is generally from the ſkin of animals, that glue is obtained: and by means of this ſubſtance many of thoſe ſkins form leather.—Tan, which is an infuſion of oak-bark in water, and may be made with nut-galls, or other aſtringent vegetables, is found, when precipitated from its ſolution, and mixed with this gluey matter, to compoſe a ſubſtance agreeing in all its properties with leather. Whence it is evident, that the proceſs of tanning is nothing elſe than the combination of the extract of oak-bark with the gluey matter of the ſkin, now called *gelatine.* Upon the diſcovery of this is founded a new and ſhorter method of tanning, than had been practiſed before.

The muſcular parts of animals are known by the name of *fleſh*: and are compoſed of fibres or threads.—Fleſh cannot be analyzed eaſily, becauſe other ſubſtances, as the fat and blood, adhere to it. If it be well waſhed in water, ſome blood, gelatinous, and ſaline matters are extracted by the water: the reſidue, being digeſted in ardent ſpirit, yields a ſoapy ſubſtance, and the remaining gelatinous matter, with the fat, may be obtained by boiling water. The water, in which the fleſh was waſhed, being evaporated ſlowly, coagulates into a ſubſtance called *albumen*, of the ſame nature with ſerum.

The *fat* of animals has the ſame properties with the fixed oils: and ſeems to be compoſed of theſe united to an acid. This acid may be obtained by diſtilling fat: an aqueous phlegm is obtained, and afterwards an acid; next an oil; and laſtly a very ſmall quantity of charcoal.

Spermaceti is a whitiſh, unctuous, fleſhy ſubſtance, found in the head of a ſpecies of whale.—It is prepared from the brains by preſſing and draining them, and afterwards ſteeping them in a ley of alkaline ſalt and quick lime—the brains are then waſhed, cut into ſlices with wooden knives, and dried.—One whale affords ſome tons.—Good ſpermaceti is in fine white flakes, gloſſy, and ſemitranſparent.—It grows yellow and rancid by expoſure to air, but may be again recovered by ſteeping it in cauſtic alkali, and waſhing it in water.

Spermaceti is employed to make candles, and is much better than tallow, being leſs fuſible and greaſy.—It is alſo of uſe in medicine; being conſidered an excellent remedy for aſthma.—It unites with oils, wax, and reſins, and in theſe forms is applied externally.—It alſo poſſeſſes the property of ſoftening the ſkin, and is for that purpoſe frequently made into paſte. A ſubſtance ſimilar to ſpermaceti has been obtained, by pouring nitrous acid upon the fleſh of animals: at the end of ſome days, after ſeparating the acid, the ſubſtance appears.

The *bones* of animals are hard and ſolid ſubſtances, to which the firmneſs, ſhape, and ſtrength of their bodies are owing. When bones are raſped and boiled in water, they afford gelatine: if kept for ſome time in acetous acid, or marine acid diluted, they become ſoft, and acquire the properties of cartilage: and if volatile alkali be poured into the acid, a white powder precipitates, which is found to be phoſphoric acid in combination with lime.—This is the ſame powder with that which remains after the burning of bones by means of their oil. If it be fuſed with mild fixed alkali, a double elective attraction takes place, the alkali uniting with the phoſphoric acid, while the lime unites with the alkaline fixed air, and forms chalk. Acids would alſo decompoſe the powder, by their ſtrong attraction to lime. By diſtillation bones yield an alkaline phlegm, oil, and much volatile alkali.

The *cruſts* and *ſhells* of fiſhes, and other animals, conſiſt in a great meaſure of the ſame ingredients which compoſe bones.—It is, probably, from the quantity of lime contained in all theſe ſubſtances, that they are ſo good manures; at leaſt this muſt have conſiderable ſhare in it.

The *bile* is a fluid of a yellowiſh green colour, a bitter taſte, and a nauſeous ſmell.—It is ſeparated from the blood by the liver, and is uſually collected in the gall bladder. When agitated it lathers like ſoap, and is employed like that in ſcouring cloths.—It is diſſolved by water, but does not unite with oils.—All the acids decompoſe it, and form coagulums, which contain mineral alkali: they are alſo found to contain a ſmall quantity of ſerous matter. By deſtructive diſtillation the bile affords a watery fluid, a yellow alkaline phlegm, an oil, and much volatile alkali; together with inflammable and fixed air. The reſidue contains mineral alkali, an earth, and a little iron.

The *biliary calculus*, or gall-ſtone, is a concrete ſubſtance depoſited in the gall-bladder.—It is of different kinds, both as to colour and properties. The calculus of a grey colour, being diſſolved in ardent ſpirit, yields cryſtals reſembling ſalt of borax: and theſe being examined, were found to be inflammable, and to have a ſtrong reſemblance to ſpermaceti.—Cryſtallized gall-ſtones, another ſpecies, contain the ſame kind of matter, in greater abundance: and it was found by M. Fourcroy in a dried human liver.

The *gaſtric juice* is that fluid which ſeems to be the menſtruum of ſolution or digeſtion of food, in the ſtomachs of animals: where it is converted into a ſoft pap, called *chyme*. That digeſtion is owing to the action of a liquid is clear from hence; that if food be contained within cloſed tubes, and paſſed through the body, it ſuffers no change except what is occaſioned by the change of temperature: whereas if theſe tubes be perforated, the fluid is converted into chyme.—The gaſtric juice is ſo various in different animals, and ſo difficult to be obtained for experiments in any, that little ſatisfactory is known on the ſubject.—It is only known that the ſtomach contains two ſubſtances, a juice containing uncombined phoſphoric acid; and a juice which has the property of coagulating milk and the ſerum of blood.

The *chyle* is a liquid reſembling milk, into which the chyme is changed, when it paſſes from the ſtomach into the inteſtines.—It contains a ſerum, globules reſembling cream, and different ſalts: probably ſome iron alſo.—It is abſorbed by the ſmall veſſels called lacteals; and is generally ſuppoſed to be ſeparated from the excrementitious matter, by means of the bile, which combines with this latter, and thus facilitates their ſeparation.

CHAP. III.

Of putrid Fermentation.

PUTRID fermentation is that natural proceſs, by which vegetable and animal ſubſtances are diſſolved and reduced into their ſimple original elements.—Thoſe bodies are moſt liable to putrefaction, which poſſeſs their juices: vegetables and animals, perfectly freed from theſe by being dried, may be preſerved in a ſound ſtate, for a very conſiderable time, even without the help of antiſeptics, or ſubſtances to defend them from corruption. The product of putrid fermentation is, for the moſt part, volatile alkali.

To carry on this proceſs completely, there are three things required; heat, moiſture, and confined air. Extreme cold and dryneſs prevent putrefaction; and a free circulation of air carries off the putrid effluvia. It ſeems, alſo, as if ſome putrifying bodies received ſome elaſtic principle from the air, which makes them ſwell and become lighter, ſo as to ſwim on the top of fluids in which they had been ſunk. But although the acceſs of air be neceſſary to carry on this natural proceſs, (as appears from bodies not putrefying in vacuo) yet it muſt only be in a very moderate quantity: for any thing like a ſtream of air would rather tend to preſerve than to corrupt.—It is perhaps owing to this, that living bodies do not putrefy; becauſe by means of reſpiration, a current of air is conſtantly paſſing into the body, the elaſtic principle is received into the blood, quickens the circulation, invigorates the powers of life, and aſſiſts the perſpiration of noxious matters.—If the elaſtic air, by which putrid bodies ſwell, be carried off more rapidly than it can be ſupplied by the heat of the atmoſphere, a principle of cold and condenſation will take place, and the putrefaction will be checked—for it is a well known fact, that evaporation produces cold, and that nothing contributes more to evaporation than a ſtrong current of air.

Putrefaction may be prevented by the addition of certain ſubſtances, which harden the texture of the body to be preſerved, and ſo prevent the admiſſion of the elaſtic principle; or by diſſolving the texture entirely, reduce it to the ſame ſtate with the proceſs of putrefaction. Thus ſalts, acids, and ardent ſpirits, defend bodies by hardening their texture; oils and gums, by excluding all acceſs of air—as in preparing mummies; and alkalies and quicklime by diſſolving the bodies.

Sugar is alſo a good antiſeptic: provided thoſe be mucilage in the body employed; which ſeems to be owing to its tendency to the vinous fermentation, a proceſs quite inconſiſtent with putrefaction. It is remarkable, that ſmall quantities of ſea-ſalt promote putrefaction. Certain airs poſſeſs the ſame qualities; as fixed air and nitrous gas. If vegetable and animal ſubſtances be mixed together, it is found that the animal ſubſtances excite the fermentation of vegetable ſubſtances, and that the latter correct the putreſcency of the former:—and that the putrefaction and fermentation of thoſe mixtures are retarded by the addition of Peruvian Bark, and other vegetable aſtringents.

APPENDIX.

CHAP. I.

Of Simple Bodies.

IN the foregoing work the arrangement of the different ſubjects was laid down, not ſo much with a view to any ſtrict rules of method, as to what was conceived the moſt eaſy and natural progreſs of the mind, ſetting out in its enquiries with familiar objects and gradually advancing to thoſe moſt remote from common apprehenſion. But the ſtudent, having by this time acquired ſome general knowledge of chemical ſubjects, may now proceed to an examination of them, beginning with the moſt ſimple ſubſtances, and tracing theſe through their various combinations. This method, which is called ſynthetical, is the uſual and moſt ſatisfactory mode of teaching any ſcience, and is always adopted, wherever firſt principles can be clearly eſtabliſhed. In natural philoſophy, and of courſe in chemiſtry which is a branch of it, this can only be done by fair and cautious experiments, and often by a nice and curious analyſis: which is the reaſon, why the knowledge of ſimple ſubſtances is frequently moſt difficult, and therefore unfit to ſet out with in a familiar treatiſe like the preſent. Wherever ſuch analyſis diſcovers two or more ingredients of different kinds in the ſame ſubject, this is evidently to be looked upon as compounded: wherever no heterogeneous parts can be diſcovered, the ſubſtance is ſo far held to be ſimple. In this reſpect then bodies may be conſidered as divided into two claſſes, 1ſt, Simple; 2nd, Compound.

Simple bodies are ſubſtances, which have never yet by any analyſis been decompoſed. They are divided by modern chemiſts into ſix claſſes as follow: 1ſt, *Caloric.* 2nd, *Light.* 3rd, *Oxygen*, 4th, *Simple combuſtible ſubſtances.* 5th, *Metals.* 6th, *Earths.* Moſt of theſe have been already diſcuſſed more or leſs in the foregoing work, though ſome of them under different names. Our preſent buſineſs is to conſider them chiefly in this new point of view, as principles of compounded bodies, until ſome future analyſis ſhall prove their own compoſition.

1ſt. *Caloric* is ſuppoſed to be a ſubſtance of a very ſubtil nature, which being diſperſed through bodies in various proportions, cauſes different degrees of heat, repelling the particles from each other, and conſtantly endeavouring to overcome their mutual attraction. So long as theſe two forces of repulſion and attraction are in equilibrium, the body remains in its natural ſtate: but if the caloric be encreaſed, this ſtate is changed from ſolid to fluid, or from fluid to vapour: and vice verſâ, by diminiſhing the caloric the body changes from vapour to fluid, or from fluid to ſolid. In theſe changes the temperature and preſſure of the atmoſphere muſt be carefully taken into account: for by encreaſing the temperature, and diminiſhing the preſſure, the body becomes more readily diſpoſed to alter its ſtate: becauſe the former adds to the quantity of caloric, while the latter ſuffers it to expand and ſeparate the particles with more eaſe. In proof of this laſt aſſertion, let a ſmall bottle be filled with ether, and a bladder tied round its neck; let it then be placed in the receiver of an air pump, through which a wire is made to paſs: when the receiver is exhauſted, let the wire be puſhed down ſo as to make a hole in the bladder, and the ether inſtantly begins to boil, changing into an elaſtic vapour which fills the receiver. In this experiment the only thing done is taking away the weight of the atmoſphere.

In a given temperature and preſſure of the atmoſphere, the different ſtates of bodies, ſolid, fluid, and aeriform, depend upon the proportion of caloric chemically combined with the body: and the aeriform, or gaſeous ſtate, is to be conſidered as the higheſt degree of ſaturation in any body with this ſubſtance. The ſeveral gaſes, therefore, are but combinations of caloric (which ſerves the purpoſe of a ſolvent) with the reſpective baſe of each gas.—Thus ſteam is water ſaturated with caloric.

Caloric is capable of exiſting in two different ſtates; *free* and *combined*. *Free caloric* is that, which paſſes from one body to another till an equilibrium be attained, producing at the ſame time ſenſible effects either upon our organs, or upon the thermometer; and hence called *ſenſible heat*. *Combined caloric* is that, which is ſo fixed in bodies by chemical affinity, as to form part of their ſubſtance, and not to exhibit ſenſible effects like the former; hence called *latent heat:* of which we have ſpoken elſewhere.

2dly. *Light* is another of thoſe ſimple ſubſtances, as modern chemiſts ſuppoſe, capable of entering into bodies, and of chemically combining with them. When vegetables grow in the light, they give out vital air, but none but noxious air in the dark, even with the application of heat. Hence it is concluded, that the ſeparation or formation of vital air from the plants, depends upon the action of light combining with it. If the calces, or as they are now called oxyds, of gold or ſilver be expoſed to light, they are revived, giving out at the ſame time vital air: and hence it muſt combine either with this air or with the metals. In the combuſtion of bodies, light is emitted; whence it ſhould ſeem to be combined either with the combuſtible body, or with vital air. Bodies, which are neither perfectly tranſparent, nor reflect all the light falling upon them, are heated by light, and the more ſo in proportion as their colours are darker. But yet light and caloric are different from each other: for flame is viſible through glaſs, yet no heat produced in the focus of a concave mirror placed beyond the glaſs; and tranſparent bodies may have light concentrated upon them, without producing the effects of caloric. Let the rays of the ſun be collected in the focus of a burning lens, upon a baſon of cold water; no ſenſible change takes place: but if a ſmall piece of dry wood be thrown in, this will be ſet on fire, and the water by means of it be made to boil. The connection and relation of light and caloric are but imperfectly known: nor is it aſcertained whether one of them be a modification of the other or not.

3ly. *Oxygen* is that ſubſtance, which forms the gravitating baſe of vital air, and combined with caloric compoſes this air, now called *oxygen gas.*—We have ſhewn in the foregoing work, that this air is indiſpenſable to reſpiration and combuſtion.

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The phenomena of combuſtion are, by the new theory, reſolved into the combination of oxygen with bodies during this operation: and to the ſame cauſe is aſcribed the acidity of bodies, which is evolved by combuſtion or otherwiſe. From this laſt property is derived the name oxygen, a word denoting the origin of ſharpneſs, or acid principle. Hence alſo thoſe bodies, with which it has been made to combine, are called *oxyds*, and the act of combining *oxydation*, or *oxygenation.*—The new theory is ſupported by theſe, among other arguments—firſt, bodies cannot be burned, nor acidified, without the preſence of oxygen: neither in a vacuum, nor in any kind of air, nor combined with any ſubſtance, which do not contain oxygen. Whereas all bodies, capable of combuſtion, or acidity, can be made to undergo theſe changes when oxygen is preſent.—Secondly, the combuſtible and the acid ſubſtances are found to gain in weight, during theſe proceſſes, preciſely ſo much as has been loſt in weight of oxygen. If ſulphur be burned in oxygen gas, or in conjunction with nitre which abounds with it, the ſulphuric acid reſulting, exceeds the weight of the ſulphur by the loſs of weight which the oxygen or nitre ſuſtains—whence it appears, that this acid is a compound of ſulphur and oxygen.

The ſame reaſoning applies to oxyds of metals, which are formed by their combination with oxygen, though this be in leſs quantity than is required to form acids.—And accordingly theſe combinations form different kinds of metallic ſalts, the oxygen working the effect of an acid.

Although the atmoſphere conſiſts of all thoſe ſubſtances, which in its preſent weight and temperature can retain the form of gaſes, together with all thoſe which can be held in ſolution by them; yet the ſtratum of air neareſt the earth, is found to conſiſt of two elaſtic fluids; one of which ſupports the reſpiration of animals, calcines metals, and burns combuſtible bodies; the other deſtroys animal life, and admits neither combuſtion nor calcination. This appears from the following experiment—if mercury be heated in a retort, whoſe neck is ſo bent as to paſs under the ſame fluid contained in a veſſel into a glaſs bell placed over it, and the quantity of atmoſpheric air contained both in the retort and bell be noted before the experiment; it will be found, that when ſo much mercury is calcined as can be, the air is reduced, having loſt one-ſixth of its bulk, and that the mercury has gained in weight; that the reduced air ſuffocates animals and extinguiſhes flame, and that the air abſorbed by the mercury during its calcination, is pure vital air, or oxygen gas. To prove this laſt point, let the calcined mercury be heated in a ſmall retort to a red heat; the metal is revived, and an elaſtic fluid is driven over, having all the properties of empyreal and reſpirable air.—Thus we ſee by analyſis what are the component parts of atmoſpheric air: and this is confirmed by ſyntheſis; for if we combine the two airs above mentioned, the reſult is found to be atmoſpheric air.

From what has now been ſaid, it ſhould ſeem that oxygen gas forms but one-ſixth part of atmoſpheric air. But this calculation is erroneous, for by more accurate methods it is ſhewn to contain twenty-ſeven parts in a hundred. The error here ariſes from a conſiderable quantity of oxygen not being abſorbed, on account of its ſtrong attraction to the mephitic air and to caloric, which its attraction to the mercury is not able to overcome.

4ly. Of ſimple combuſtible ſubſtances there are five kinds, *phoſphorus*, *ſulphur*, *carbon*, *hydrogen*, and *azot*. *Phoſphorus* and *ſulphur* have been already treated pretty much at large. It will be ſufficient here to ſtate an experiment, which will ſhew the production of phoſphoric acid from the combination of phoſphorus with oxygen, as alſo the proportion of theſe ingredients in the compoſition.

Let a bell-glaſs filled with oxygen gas be placed over well dried mercury, and a certain weight of phoſphorus in a ſmall cup be laid upon the ſurface of the mercury; if a crooked iron wire made red hot be introduced, the phoſphorus taking fire will burn rapidly with a brilliant flame, and the inſide of the glaſs will be covered with white flakes of phoſphoric acid. By computing the weight of oxygen loſt, and that of the phoſphorus conſumed by combuſtion, it is found that 100 parts of phoſphorus require 154 parts of oxygen for ſaturation; and that the combination produces 254 parts of concrete phoſphoric acid. In this proceſs, phoſphorus is changed from a combuſtible into an incombuſtible ſubſtance, and from an inſoluble into a ſoluble one, which attracts moiſture rapidly from the air, and thus forms a liquid conſiderably heavier than water.

The ſame reſults would probably follow from the combuſtion of ſulphur, which is known to produce ſulphuric acid, by abſorbing oxygen. But the ſame accuracy cannot be attained here as in the former caſe: becauſe the acid is not ſo eaſily condenſed; and becauſe ſulphur burns with more difficulty, and is ſoluble in the different gaſes.

Sulphur and phoſphorus combine with ſeveral other ſubſtances. Theſe combinations are called in the modern ſyſtem by the names of *ſulphurets* and *phoſphorets*: thus the union of ſulphur with lead is called Sulphuret of Lead; the union of phoſphorus with iron, Phoſphoret of Iron; and ſo of all others.

Carbon is the next of thoſe ſimple combuſtible ſubſtances, and is but another name for charcoal, when this is freed from earths and ſalts. The general method of preparing it has been already mentioned; but this may be done more accurately by burning wood in a crucible, covered with ſand, and kept red-hot for ſome time. The reſult is a black ſhining ſubſtance, brittle, and without taſte or ſmell. The moſt violent fire (if air be excluded) has no other effect than to harden it: but when heated in the open air to 370°, it takes fire, and, if quite pure, burns away without leaving any reſidue. In cloſe veſſels containing oxygen gas it likewiſe burns, abſorbing oxygen, and forming with it a gas called *carbonic acid*, which is juſt equal in weight to the quantities of carbon and oxygen conſumed. This gas contains 28 parts by weight of carbon, and 72 of oxygen; and is the ſame in its properties with what was called *fixed air*. It does not condenſe in the common temperature and preſſure of the atmoſphere, but remains in the form of a gas, requiring a large quantity of water to be diſſolved in.

Carbon is capable of being cryſtallized, in which ſtate it is proved, by an experiment of Mr. Tennant, to be the *diamond*. He burnt together in a cloſed tube about 2½ grains of diamond with ¼ of an ounce of nitre, by a ſlow heat. The volatile product, which conſiſted of diamond gas and oxygen of nitre, was imbibed by the alkali of the nitre; which being diſſolved in water, and ſome marine acid and lime added to the ſolution, a double attraction took place, and the lime, united with the oxygenated gas, was precipitated. The fluid was then decanted off, and the precipitate put into a vial full of mercury, which was inverted into another veſſel containing the ſame: the lime by its levity roſe to the top. An acid was then introduced, which had a ſtronger affinity to lime than the oxygenated gas had:

this laſt was of courſe ſet free, and found to be a true carbonic acid gas, both in its properties, and the proportion of its component parts; the diamond gas, which weighed $2\frac{1}{2}$ grains, having the ſame proportion to the oxygen conſumed, as 28 to 72, and each of them to the weight of the whole compound gas, as theſe numbers reſpectively to 100.

The diamond can be entirely volatilized (if air be preſent) by an heat ſomewhat greater than what melts ſilver. A remarkable experiment was made by Francis I. of France, upon diamonds and rubies; which were put in different veſſels, and expoſed to a violent heat for twenty-four hours. At the end of that time the veſſels were opened; no trace was found of the diamonds, while the rubies had not undergone any change, either in colour, weight, or ſhape. It was thought by ſome, that the diamond may be volatilized without contact of air: but later and more accurate experiments have ſhewn, that no change is produced under ſuch circumſtances. And this is a further analogy between the diamond and carbon.

Diamonds are generally found in a yellow ochre, or in rocks of freeſtone and quartz; ſometimes in running water: theſe laſt are brilliant, the former not ſo. They are ſo hard as to receive no impreſſion from the beſt-tempered ſteel; and muſt be ground by rubbing them againſt each other. In the rough form, they are worth two pounds ſterling the carat, or one fourth of a grain, provided they are without blemiſh: the expence of cutting and poliſhing amounts to about four pounds more. The value, however, is far above what is now ſtated, when they become conſiderable in ſize.

Charcoal is not liable to rot like wood: it may for this reaſon be uſefully employed for ſtakes to fix in the earth, and for other purpoſes. If boiled with meat tending to putrefaction, it is thought to cure and reſtore it. The combinations with charcoal are in the new ſyſtem called *carburets;* as carburet of iron, &c. &c.

Hydrogen is that ſimple combuſtible ſubſtance, which forms the gravitating baſe of inflammable air, now called *hydrogen gas.* It is called by this name, becauſe by combuſtion, or combination with oxygen, it forms water, as has been already mentioned, and will more ſatisfactorily be ſhewn in the next chapter. In the mean time let it be here aſſumed as true.

Hydrogen gas may be obtained by immerſing in water any ſubſtance, as red hot iron or carbon, which has ſtronger affinity to oxygen than hydrogen has: this laſt is ſet free, and combining with caloric goes off in the form of a gas. It may be had in greater abundance by pouring ſulphuric acid upon filings of iron. It diſſolves ſulphur, phoſphorus, and carbon, forming compounds which are reſpectively known by the names of *ſulphurated*, *phoſphorated* and *carbonic, hydrogen gas.*

Sulphurated hydrogen gas is the ſame which was formerly mentioned under the name of *hepatic gas*, and may be diſengaged by acids or water from hepars (or as they are now called ſulphurets) whether of lime or alkalies. For inſtance, if ſulphuric acid be poured upon any ſulphuret, the water accompanying the acid is decompoſed by the ſulphur attracting its oxygen, and thus its hydrogen being ſet free diſſolves the remaining ſulphur, to which it has a ſtrong affinity. The ſame gas may alſo be obtained by incloſing ſulphur in a glaſs filled with hydrogen, and melting the ſulphur with a burning lens: the hydrogen gas becomes ſulphurated, and aſſumes all the properties of hepatic gas.

Phoſphorated hydrogen gas is procured by diſſolving a mixture of phoſphorus and potaſh in boiling water: phoſphorated acid is in this proceſs formed by the phoſphorus combining with the oxygen of the water, while the hydrogen, being ſet free, diſſolves part of the phoſphorus and flies off in the form of a gas. If this gas be mixed with oxygen, or even with atmoſpheric air, it becomes luminous; and with a ſlight heat burns rapidly, yielding water and phoſphoric acid.—And hence it appears, that this combuſtion is nothing more than the ultimate union of oxygen with the conſtituent parts of the gas; for the ſame effects are produced by both.

Carbonic hydrogen gas may be obtained in different ways: by expoſing vegetables to a red heat; by combining ſulphuric acid with ſpirit of wine; by paſſing ether through a red hot glaſs tube, &c.: and it riſes ſpontaneouſly from marſhy grounds, though in this laſt caſe mixed with other gaſes. Theſe different effects may be explained by the ſame principle, viz. that hydrogen and carbon form a great part in the compoſition of vegetable as well as animal ſubſtances: and when by any means theſe principles are made to combine in the gaſeous ſtate, they compoſe carbonated hydrogen gas. For inſtance when vegetables are expoſed to a red heat, their oxygen (which is alſo an ingredient in them) combines with part of the carbon, to which it has a very ſtrong affinity at this degree of heat, forming carbonic acid; and the hydrogen, combining with a portion of the carbon, flies off in the form of the gas now under conſideration. Again, when ſulphuric acid combines with ſpirit of wine, the acid, or the water accompanying the acid is decompoſed by the carbon attracting its oxygen in the degree of heat occaſioned by the mixture, and the hydrogen combines with another portion of the carbon in the gaſeous ſtate.

Azot forms the gravitating baſe of that mephitic air, which remains after ſeparating oxygen gas from atmoſpheric air. In the common preſſure and temperature it is always in the ſtate of a gas, called *azotic gas*, which makes about 73 parts in 100 of the atmoſphere. Azot is a conſtituent part of animal bodies, being combined in them with hydrogen, carbon, and ſometimes phoſphorus. It forms in conjunction with oxygen the nitrous acid, of which it compoſes about 13 parts in 100, the remaining 87 being oxygen. This may be ſhewn by introducing the two gaſes in theſe proportions above mercury in an inverted glaſs veſſel, and by paſſing the electric ſpark through them, to form their union: the gaſes gradually diſappear, and nitrous acid is found in their place. In this experiment caloric flies off, while azot and oxygen by their union from the acid. When combined with hydrogen, azot forms volatile alkali, now called *Ammoniac.*

Azotic gas may be obtained by putting ſulphuret of potaſh or of lime in a glaſs veſſel filled with atmoſpheric air, and well cloſed: upon the application of heat, all the oxygen is ſoon abſorbed, leaving the azotic gas behind. This gas, though it ſhould ſeem to be a very compounded ſubſtance, by reaſon of the great number of exhalations and vapours, to which the atmoſphere is liable, has yet never been analyzed and is therefore conſidered as a ſimple ſubſtance. It compoſes nearly two thirds of the atmoſphere.

5th, *Metals* are another claſs of ſimple bodies laid down in the modern ſyſtem. Theſe have been examined pretty much at large in the foregoing treatiſe; ſo that it will not be neceſſary to dwell upon this part of the ſubject farther than to make ſuch obſervations as ariſe out of the new theory.

1ſt Then, it ſhould be obſerved that the calces of metals are now looked upon as combinations of them with oxygen, and are therefore called *oxyds*: and 2ndly, that no metal can unite with an acid unleſs it be firſt reduced to the oxyd ſtate, by attracting oxygen either from the acid or from the water accompanying the acid, by which means a decompoſition of the acid or water takes place previous to the formation of the neutral metallic ſalt. And hence it is, that when a metal is preſented to an acid capable of diſſolving it, an effervescence takes place which is owing to the diſengagement of ſome gas either from the acid or water, upon its being ſet free from oxygen. Thus, when a metal is diſſolved in nitrous or as it is now called *nitric acid*, which conſiſts of oxygen and azot, this laſt always eſcapes. But if the acid be ſulphuric, the gas which eſcapes is ſulphureous or hydrogen, according as acid itſelf or the water is decompoſed. In the caſe of nitric acid it may be thought that hydrogen ſhould alſo eſcape upon the decompoſition of its water: but it combines with the oxygen of the nitric acid, forming new water, while the azot eſcapes; oxygen being much more abundant in this than in ſulphuric acid, and having leſs affinity to azot than to hydrogen.

The ſame principle ſhews why metallic oxyds are diſſolved in acids without effervescence; becauſe, being already ſaturated with oxygen, they do not decompoſe the acid or water by attracting their oxygen, and of courſe do not diſengage any gas, by which diſengagement the efferveſcence is occaſioned. And on the ſame account metals are inſoluble in an acid, unleſs they have a ſtronger affinity to oxygen, than the baſe of the acid has.

Metals are not capable of becoming oxyds by arbitrary combinations with oxygen, or even in a great variety of degrees. For the moſt part the oxyds of one metal are not above two: in ſome are three. But ſtrictly and philoſophically ſpeaking, it ſhould ſeem that there ought not to be more than one, viz. that which is produced by ſaturation with oxygen, and that the reſt are imperfect in proportion as they deviate from this.

Gold is capable of two oxyds, *the yellow and the purple:* the yellow is obtained by precipitating gold from its ſolution in aqua regia with lime. Neither the difference of theſe oxyds, nor the proportion of oxygen in each, have been clearly aſcertained.

The oxyds of ſilver are two, *the black and the blue.* One of theſe is compoſed of about ninety parts metal, and ten oxygen. It is procured by precipitating ſilver from its ſolution in nitric acid with lime.

It is doubtful whether copper has two or three oxyds, but the latter is thought more probable;

theſe are the *brown*, *blue*, and *green*. The brown is had by combuſtion; the blue by precipitating copper from its ſolution in ſulphuric acid, with lime; the green by diſtilling nitric acid off copper. The brown oxyd contains about eighty-four parts metal, and ſixteen oxygen.

Iron has two oxyds, the *green and brown*. The green is obtained by precipitating iron from its ſolution in ſulphuric acid with alkali: it contains about ſeventy-three parts metal, and twenty-ſeven oxygen: the brown, by expoſing the former to air, it conſiſts of fifty-two parts iron, and forty-eight oxygen.

Lead has three oxyds, *the white*, *yellow*, *and red*, anſwering to the calces before mentioned, viz. white lead, litharge, and minium. The white conſiſts of about ninety-five parts lead, and five oxygen; the red of eighty-eight parts lead, and twelve oxygen; the yellow ſome proportion between theſe extremes.

There are two oxyds of tin, *the grey and white*: the former is procured by heating tin in contact with air, and contains ninety parts tin, and ten oxygen: the latter is the powder ſublimed during a red heat, conſiſting of ſeventy-ſeven parts tin, and twenty-three oxygen.—This laſt oxyd is called the *ſtannic acid*.

Mercury is thought to contain three oxyds, *the black*, *yellow*, *and red*, which ſeem to anſwer to the three calces before metioned, viz. Ethiops per ſe, turbith mineral, and red precipitate. The proportion of oxygen in the firſt is not aſcertained; in the yellow there are above ninety-ſix parts mercury, and above three oxygen; in the red above ninety-two of mercury, and above ſeven of oxygen.

Antimony has two oxyds, *the grey and white*. The grey is procured by gentle heat in contact with air; the white, by a melting heat which ſublimes it in flowers.—This laſt conſiſts of ſeventy-ſeven parts antimony, and twenty-three oxygen.

Biſmuth gives two oxyds, *the brown and white*. The brown is formed by ſubliming it in contact with air, and conſiſts of ninety-four parts biſmuth, and ſix oxygen: the white is a precipitate from its ſolution in nitric acid made by adding water, and contains eighty-four parts biſmuth, and ſixteen oxygen.

Of zinc there are two oxyds, *the grey and white*. The grey is procured from melting zinc in a moderate heat, and conſiſts of eighty-five parts zinc, and fifteen oxygen: the white is ſublimed by a ſtronger heat, and contains more oxygen than the former.

Arſenic has two oxyds, *the grey and white*. The grey is formed by expoſure of arſenic to air; the white is ſublimed by heat, and conſiſts of ninety-three parts arſenic, and ſeven oxygen.

Cobalt yields *a dark blue oxyd*, both by heat, and ſolution in nitric acid: in the former caſe, the oxyd contains eighty-eight parts of cobalt, and twenty-three of oxygen. Nickel gives a *brown* oxyd, conſiſting of ſeventy-ſeven parts nickel, and twenty-three oxygen.

Manganeſe has two oxyds, *a black and white*. The black may be had by expoſure of manganeſe to air, but better by the action of heat, conſiſting of ſeventy-five parts manganeſe, and twenty-five oxygen; the white, by pouring muriatic acid upon the black oxyd, and contains eighty parts manganeſe, and twenty oxygen.

Theſe are the principal matters relative to metals ariſing from the new theory. As to their combinations with ſulphur, phoſphorus, and carbon, ſuch of them as have been applied to uſe, or ſeemed to contain any important principle, have been already examined, ſo far as the nature of this work would admit.

6th. The laſt claſs of ſimple bodies to be mentioned are earths, of which eight kinds are enumerated, viz. Lime, Magneſia, Barytes, Silica, or pure ſiliceous earth, Alumina, or pure argillaceous earth, Strontites, Jargonia, and Adamanta. The five firſt have been already examined.

The *ſtrontites*, found in the ore of a lead mine of Strontian in Argyleſhire, conſiſts of carbonic acid, and a peculiar earth: the acid may be ſeparated by heat. The earth is white, and has a pungent taſte and ſmell. It may be diſſolved in hot water: the ſolution affords cryſtals, which contain about ſixty-eight parts of water in 100. Theſe cryſtals, by expoſure to air, attract carbonic acid, and fall to powder.

Jargonia is the earth of a precious ſtone called jargon, which is found in Ceylon. This ſtone is of various colours, and often cryſtallized. In a melting heat little of its weight is loſt: it reſiſts all action of the acids, unleſs it be diſſolved in mineral alkali, when it is acted upon by the muriatic acid, and found to contain thirty-eight parts ſilica, five of a mixture of nickel and iron, the remaining fifty-ſeven a peculiar earth.

Adamanta is the earth of an adamantine ſpar found in the Eaſt. The ſpar is grey, cryſtallized, and ſo very hard as to cut glaſs. When analyſed (which is extremely difficult) it is found to contain alumina and adamanta.

It was a conjecture of M. Lavoiſier, that the primitive earths are only metallic oxyds, whoſe oxygen is ſo ſtrongly combined with their baſes, as not to be ſeparable by its affinity to carbon; and that on this account they have not yet been reduced to the metallic ſtate. And his conjecture ſeems to be confirmed by ſome experiments made upon chalk, magneſia, and barytes: which being (in a pure ſtate) mixed with charcoal, and made into a paſte with oil; then ſurrounded with charcoal, and ſubmitted to a ſtrong melting heat for about two hours, afforded metallic buttons.—Yet ſome have objected, that theſe are derived either from the charcoal, or crucibles which contain metallic matters, and can no more be conſidered as diſtinct metals, than ſiderite, now known to be phoſporated iron, or plumbago carbonated iron.

CHAP. II.

Of Compound Bodies.

UNDER the head of Compound Bodies are claſſed thoſe, which conſiſt of two or more ſimple ſubſtances. Of the firſt kind are reckoned five in number, viz. 1ſt, *Water;* 2dly, *Alcohol;* 3dly, *Oils;* 4thly, *Alkalies;* 5thly, *Acids.*

1. Many of the properties of water have been already examined; and the moſt important matter now remaining is to prove, that it is compounded of two ſimple ſubſtances, oxygen and hydrogen, which is ſhewn both by analyſis and ſyntheſis; analytically by the following experiments.

A long glaſs tube, well annealed and coated over, was laid almoſt horizontally acroſs a furnace. At the higher end it was luted to a retort containing diſtilled water; at the lower to a worm, which was fitted to the neck of a glaſs veſſel; and in this veſſel was alſo inſerted a bent tube, through which any elaſtic products may eſcape into a proper apparatus. Fires being lighted in the furnace above mentioned, and in another under the retort, the water was diſtilled over into the glaſs veſſel, without any change in its weight or properties.

Matters being again diſpoſed as before, twenty-eight grains of carbon were put into the long tube over the furnace. When the water was all diſtilled, the carbon had vaniſhed, and the elaſtic products were found to conſiſt of carbonic acid and hydrogen gaſes. Now carbonic acid gas being known to contain twenty-eight parts of carbon, and ſeventy-two of oxygen in an hundred, by ſubducting the former we have the weight of the latter, which added to the weight of the hydrogen, viz. about $13\frac{1}{2}$ grains, is found to be the weight loſt by the water, viz. about $85\frac{1}{2}$ grains. Whence it appears, that part of the water was converted into theſe two gaſes, nearly in the proportion to each other of 72 oxygen to $13\frac{1}{2}$ hydrogen.

Again: in place of the carbon was put ſoft iron in thin plates, ſpirally rolled up, to the amount of 274 grains: the reſult now is, that the iron has acquired eighty-five grains, the elaſtic product contains fifteen, and the water has loſt the ſum of both, viz. an hundred. But the iron has gained oxygen, being a true oxyd; and the elaſtic product is hydrogen gas; ſo that the ſame effect follows as before, and the proportion ſtill continues: 85 being to 15 as 72 to a little above $13\frac{1}{2}$.

The concluſion eſtabliſhed by this analyſis is ſynthetically confirmed by the following experiment. A large hollow globe or balloon of glaſs has its neck ſo contrived, as to admit four tubes to be inſerted; one for exhauſting it of air, two more for conveying into the balloon oxygen and hydrogen gaſes; and the fourth to paſs a wire with a knob at the end, for the purpoſe of conveying the electric ſpark within the balloon to the hydrogen tube: the three firſt tubes are furniſhed with ſtop-cocks. The balloon, being exhauſted of air, is filled with oxygen gas, well purged from all moiſture and ſaline matter, and then pure hydrogen gas is preſſed in. This laſt ſoon receives fire from the electric ſpark; and the combuſtion may be continued at pleaſure by keeping up a ſupply of the gaſes. As the proceſs goes on, water is formed; its weight found equal to the weights of the oxygen and hydrogen employed; and the quantities of each of theſe gaſes in the proportion above ſtated of eighty-five to fifteen.

Theſe experiments were made by Lavoiſier, and were afterwards repeated with great accuracy by Fourcroy and others, giving nearly the ſame reſults. The ſmall differences may ariſe from different temperatures, the different ſubſtances uſed to obtain the gaſes, &c. &c. but do not effect the main point. It was Mr. Cavendiſh, who firſt produced water by burning hydrogen gas with common air, and afterwards with oxygen gas. Mr. Watt, however, it ſeems, had conceived the ſame idea of its compoſition, before Cavendiſh had publiſhed his experiment.

2. *Alcohol*, or Spirit of Wine, has been already treated of. It is one of the reſults of vinous fermentation from ſaccharine ſubſtances; which conſiſting of oxygen, carbon, and hydrogen, are reduced into two portions; one part conſiſting of oxygenated carbon or carbonic acid; the other of hydrogen combined with carbon, or alcohol. Theſe principles of the alcohol do not exiſt in the ſtate of oil, but are united to a portion of oxygen, which makes them capable of mixing in water: ſo that in ſtrictneſs, alcohol conſiſts of three principles in a ſort of equilibrium, which being deſtroyed, theſe elements become re-combined two and two, forming water, oil, and carbonic acid.

3. Oils have likewiſe been examined before. They are compoſed of hydrogen and carbon, and may be converted into vegetable oxyds, or even acids, by the addition of oxygen. Sugar, for inſtance, is a vegetable oxyd, conſiſting of an oil, or, perhaps, ſpeaking more accurately, of the principles of an oil, united to oxygen; of which laſt it contains ſixty-four parts, of hydrogen eight, and of carbon twenty-eight in an hundred. Lavoiſier analyzed olive oil, and found it to conſiſt of ſeventy-nine parts carbon, and twenty-one hydrogen.

4. The three alkalies, called vegetable, mineral, and volatile, ſpoken of pretty fully elſewhere, are now ſeverally known by the names of *potaſh*, *ſoda*, and *ammonia.* There is a ſtrong affinity between theſe ſubſtances and acids: whence in the proceſs of making potaſh from the combuſtion of vegetables, ſome carbonic acid, formed by the union of oxygen with their carbon, remains attached to it. This may be eaſily ſeparated, by adding to a ſolution of potaſh in water, two or three times the weight of quicklime, to which the carbonic acid has a greater affinity: the potaſh now becomes ſoluble in alcohol; and Berthollet employs this property to procure it in perfect purity.

Potaſh readily unites with ſulphur, forming with it *ſulphuret of potaſh:* it may be procured either by melting the ingredients together, or by boiling them in water till they are diſſolved, and filtering the ſolution. This ſulphuret, when moiſtened with water, abſorbs all the oxygen contained in the ſame veſſel with it; and if in the ſame ſtate expoſed to the atmoſphere, it attracts ſo much oxygen, as converts its ſulphur into ſulphuric acid. Potaſh does not combine with metals unleſs they are oxydated, as appears from what was formerly ſaid under the heads of Glaſs and Enamel.

Soda has many properties in common with potaſh, though ſome diſtinctive characters: neither of them have yet been analyzed, nor is it known with certainty, whether they are compounded ſubſtances or not, although it is moſt probable they are ſo; for, from late experiments, ſoda is thought to be a modification of magneſia, which is by ſome accounted a metallic oxyd, as before mentioned; and by analogy we may conclude the ſame of potaſh.

Ammonia is found by analyſis to contain, in 1000 parts, 807 of azot, and 193 of hydrogen. It is chiefly procured from animal ſubſtances by diſtillation, but impure, being mixed with oil and water, and often ſaturated with carbonic acid. It is purified by firſt adding an acid, *e.g.* the muriatic, and afterwards an alkali. Ammonia may be formed ſynthetically by combining the two gaſes above mentioned; as appears from putting iron filings moiſtened with water into a ſmall veſſel filled with azot: the iron decompoſes the water by attracting its oxygen, while the hydrogen of the water, being ſet free, combines with the azot, and forms ammonia.

5. Acids: the moſt important of theſe have been already examined. The ſulphuric acid contains about ſixty-three parts ſulphur, and near thirty-ſeven oxygen. It oxydates moſt metals, and unites with all the alkalies and ſeveral of the earths. Its combinations are called *ſulphats*: thus green vitriol is *ſulphat of iron*, blue vitriol *ſulphat of copper*, white vitriol *ſulphat of zinc*, gypſum or ſelenite *ſulphat of lime*, Glauber's ſalt *ſulphat of ſoda*; and ſo of all others. There is

another combination of ſulphur with a leſs quantity of oxygen than goes to the formation of ſulphuric acid: this in the new ſyſtem has the name of *ſulphurous acid*, and its various combinations with other ſubſtances are called *ſulphites*. The terms ſulphat and ſulphite, as applied to metals, anſwer to the two different degrees of oxydation, which take place in ſeveral of them.

Nitric acid, formerly called nitrous acid, conſiſts of two principles azot and oxygen: and according to the different proportions of theſe it obtains different names, viz. nitric acid ſaturated with oxygen, nitrous acid containing a much leſs quantity, and nitrous gas, ſtill leſs. Lavoiſier eſtimates the proportion of oxygen to azot in nitric acid to be nearly four to one. Cavendiſh makes it not more than three to one: the proportion in nitrous gas is about two to one. In diſtilling nitre with ſulphuric acid, nitrous and not nitric acid is obtained, by reaſon of a great quantity of oxygen eſcaping with caloric, to which in a *high temperature* it has a ſtronger affinity than to nitrous acid: and hence there is not enough of oxygen to form nitric acid. However by heating the acid ſo obtained over a gentle fire, the ſuperabundant nitrous gas eſcapes, and the due proportion for compoſing nitric acid is reſtored. Again, if a glaſs be filled with nitric acid, and inverted into a veſſel containing the ſame, the acid in the glaſs is, by expoſure to light, decompoſed; the upper part of the glaſs containing oxygen over the acid now changed into nitrous. And hence alſo it appears that nitric acid is compounded of nitrous acid and oxygen.

Nitre may be formed by a combination of azot and oxygen with potaſh; viz. by introducing a mixture of theſe gaſes into a tube above mercury, till it occupies three inches of the tube, and a ſolution of potaſh filling about half an inch; and then paſſing through the tube ſeveral electrical ſparks till the gaſes vaniſh. The reſult is found to be nitre: the gaſes therefore compoſe nitric acid, when the caloric eſcapes.

The combinations of nitric acid with different ſubſtances are called *nitrats*, as *nitrat of ſoda*, or nitre, *nitrat of potaſh*, or cubic nitre; *nitrat of ſilver*, or lunar nitre. And ſo of the reſt. Combinations of nitrous acid are called *nitrites*.

Muriatic acid has not yet been decompoſed by chemical experiments. Berthollet conjectures its baſe to be of a metallic nature: others ſuppoſe it to be ſulphurated hydrogen, and ſupport their opinion in the following manner. If ſulphurated hydrogen gas be diſſolved in water, and iron be added to the ſolution, after ſome time a ſalt is obtained by evaporation; on which if ſulphuric acid be poured, a vapour is diſcharged ſimilar to muriatic gas in its properties. One of theſe is, that paper moiſtened with lime water being held over the vapour, exhibits the appearance of a grey ſmoke. Oxygen being in this proceſs attracted by the iron, the gas which flies off muſt of courſe be ſulphurated hydrogen.

Muriatic acid, obtained in the common way of diſtilling ſea-ſalt with ſulphuric acid, is capable of combining with ſtill more oxygen, by being diſtilled from the oxyds of manganeſe, lead, or mercury. In this laſt ſtate it was called dephlogiſticated, but is now called *oxygenated muriatic* or *oxy-muriatic acid;* it is in the form of a gas, which, like the former, is abſorbed by water, though in leſs quantity; after a certain point of the abſorption, the acid falls to the bottom in a concrete form. Both theſe acids oxydate and diſſolve ſeveral of the metals. All their combinations with different ſubſtances derive their names from the acids: thoſe of the former being called *muriats*, and thoſe of the latter, *oxy-muriats*; thus *muriat of potaſh*, or ſalt of ſylvius, *muriat of ſoda*, or common ſea-ſalt, *muriat of ammonia*, or ſal-ammoniac, &c. &c.; and thus alſo *oxy-muriat of mercury*, or corroſive ſublimate, which may be made by diſſolving mercury in this acid.

Muriatic acid poſſeſſes the power of deſtroying putrid exhalations; probably from its cloſe affinity to volatile alkali, which makes a conſiderable part of them.

Oxy-muriatic acid is at preſent much uſed in *bleaching*, on account of the extraordinary quickneſs with which it is found to compleat the proceſs, by its known property of diſſolving the extractive matter of vegetables, and rendering them colourleſs. This is owing to its ſuperabundant oxygen: for oxygen is a principle which ſeems indiſpenſable to the proceſs, in whatever method it may be conducted, and explains the reaſon of expoſing cloth to air and water, as well as every other means uſed in the manufacture of bleaching. How far the acid may injure the cloth, is not yet aſcertained; and perhaps this may depend upon the baſe of the acid, rather than on its acidifying principle.

To the remaining acids mentioned in the courſe of this work, it will be ſufficient to give their names according to the new ſyſtem; as a more detailed examination of them would exceed the limits firſt propoſed.

Acid of	Phoſphorus	-	*Called*	Phophoric
———	Borax	-	———	Boracic.
———	Fluor Spar	-	———	Fluoric.
———	Amber	-	———	Succinic.
———	Sugar	-	———	Oxalic.
———	Tartar	-	———	Tartarous.
———	Lemons	-	———	Citric.
———	Apples	-	———	Malic.
———	Vinegar	-	———	Acetic.
———	Galls	-	———	Gallic.
———	Camphor	-	———	Camphoric.
———	Benzoin	-	———	Benzoic.
———	Milk	-	———	Lactic.
———	Sugar of Milk	-	———	Saccolactic.
———	Pruſſian blue	-	———	Pruſſic.
———	Ants	-	———	Formic.
———	Fat	-	———	Sebacic.
———	Animal Subſtances		———	Zoonic.

The ſubſtances treated under the different heads in this chapter, are conſidered as compounded of two ingredients only. There are many others, which conſiſt of more, and which, being made up of bodies compounded in themſelves, are ſometimes on that account called doubly compound. Of theſe we ſhall take but a ſlight notice; the principal of them having been already examined at ſome length.

Soaps are ſubſtances of a doubly compound kind; becauſe whether they be alkaline or acid, or of any other ſpecies, they are formed by compounded bodies. Thus alkaline ſoaps are combinations of oils and alkalies; earthy ſoaps are combinations of the alkaline with earths, as ſoap of lime is produced by pouring lime-water into a ſolution of common ſoap, ſoap of magneſia by mixing ſolution of common ſoap with ſulphat of magneſia; metallic ſoaps are combinations of the alkaline with oxyds of metals, as ſoap of iron is a combination of common ſoap with ſulphat of iron, ſoap of tin a combination of it with a ſolution of tin in nitro-muriatic acid, &c. &c.

Acid ſoaps are combinations of an acid with different kinds of oils. Theſe combinations have yet been found to take place only with the ſulphuric acid; and may be made by gradually mixing three parts of the boiling oil with two parts of the acid, and triturating them well together.

Neutral ſalts are another of the ſame ſpecies; being combinations of acids with alkalies, earths, or metallic oxyds, which are called the ſeveral baſes of thoſe ſalts. Hence there are as many orders of ſalts as there are kinds of acids; and as many ſpecies of ſalt in each order, as there are different baſes capable of uniting with them. But beſide theſe are other ſalts called *triple ſalts;* which conſiſt either of two acids combined with one baſe, or two baſes combined with one acid.

Of the former we have an example in the combinations of nitro-muriatic acid with various ſubſtances; which are called *nitro-muriats*, as nitro-muriat of lime, magneſia, &c.: and of the latter, in the ſulphats, nitrats, and muriats of ſuch ſubſtances as conſiſt of two baſes, like ammonia, &c.

It may here be obſerved, that as the names of ſulphat, nitrat, and muriat are derived from their reſpective acids, ſo the names of phoſphat, fluat, oxalat, acetite, tartrite, &c. mean the combinations of theſe ſeveral acids with different ſubſtances.

Thus the principles, from which the new nomenclature is derived, being known, its conſtruction appears to be ſimple and comprehenſive, and capable of being eaſily extended to an infinite variety of ſubjects, whether of real or imaginary exiſtence. The following table contains ſome of the moſt remarkable combinations, which were diſtinguiſhed by particular names under the old ſyſtem, with their correſpondent names in the new. They are arranged according to the order of elective affinities between the ſeveral principles and the reſpective baſes.

COMBINATIONS OF

CALORIC, OR PRINCIPLE OF HEAT.

With	*New Names.*	*Old Names.*
Oxygen	Oxygen gas	Vital air.
Hydrogen	Hydrogen gas	Inflammable air.
Azot	Azotic gas	Nitrous gas.

OXYGEN, OR BASE OF VITAL AIR.

Carbon	Carbonic acid	Chalky acid.
Metals	Oxyds	Calces.
Sulphur	Sulphuric acid	Vitriolic acid.
Phoſphorus	Phoſphoric acid	Phoſphoric acid.
Azot	Nitric and nitrous acid	Nitrous acid.

HYDROGEN, OR BASE OF INFLAMMABLE AIR.

Azot	Ammonia	Volatile alkali.
Oxygen	Water	Water.

CARBON, OR FINE CHARCOAL.

Iron	Carburet of iron	Plumbago.

SULPHUR.

Copper	Sulphuret of copper	Pyrites.
Iron	——— iron	
Zinc	——— zinc	
Vegetable alkali	——— potaſh	Alkaline hepars, or livers of ſulphur.
Mineral alkali	——— ſoda	
Volatile alkali	——— ammonia	
Lime	——— lime	Calcareous liver of ſulphur.
Magneſia	——— magneſia	Magneſian liver of ſulphur.
Hydrogen gas	Sulphurated hydrogen gas	Hepatic gas.

SULPHURIC ACID.

With	*New Names.*	*Old Names.*
Barytes	Sulphat of barytes	Marmor metallicum.
Vegetable alkali	——— potaſh	Vitriolated tartar.
Mineral alkali	——— ſoda	Glauber's ſalt.
Lime	——— lime	Gypſum, or ſelenite.
Magneſia	——— magneſia	Epſom ſalt.
Volatile alkali	——— ammonia	Vitriolic ammoniac.
Clay	——— alumina	Alum.
Zinc	——— zinc	White vitriol.
Iron	——— iron	Martial or green vitriol.
Copper	——— copper	Blue vitriol.

NITRIC ACID.

Vegetable alkali	Nitrat of potaſh	Nitre.
Mineral alkali	——— ſoda	Cubic nitre.
Volatile alkali	——— ammonia	Nitrous ammoniac.
Metallic calces	Nitrats of thoſe metals	Nitrous ſolutions.

MURIATIC, OR MARINE ACID.

Barytes	Muriat of barytes	Ponderous marine ſalt.
Vegetable alkali	——— potaſh	Salt of Sylvius.
Mineral alkali	——— ſoda	Common ſalt.
Lime	——— lime	Marine ſelenite.
Magneſia	——— magneſia	Magneſian marine ſalt.
Volatile alkali	——— ammonia	Sal ammoniac.
Clay	——— clay	Argillaceous marine ſalt.
Nitric acid	Nitro-muriatic acid	Aqua regia.
Oxygen	Oxy-muriatic acid	Dephlogiſticated marine acid.